

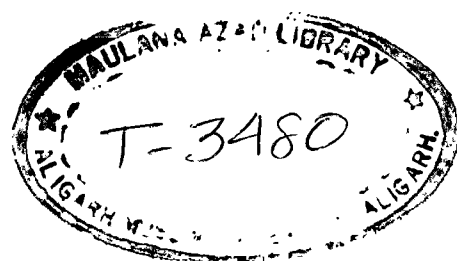


# **MINERALOGY AND GEOCHEMISTRY OF 'REH' SOIL IN SOME PARTS OF U.P.**

*By*  
**MOHD. AJMAL ANSARI**  
*M. Sc., P. G. Dip. Hydrogeol, M. Phil. (Alig.)*

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## ABSTRACT

As a part of the arid and semi-arid landscape, saline and alkali lands have been known to occur in India from time immemorial, more prominently in the Indus and Gangetic plains in the north.

The vernacular names 'Reh', 'Usar' or 'Kallar' have been in use for the saline efflorescence forming a crust on the surface of the soils during the dry periods. The efflorescence essentially consists of a mixture of sodium carbonate, bicarbonate, chloride and sulphate, together with varying proportions of calcium and magnesium salts. In the Indo-Gangetic Plain, the state of Uttar Pradesh (U.P.) is particularly affected by these deposits, most of which occur along certain belts which generally run along NW-SE.

The salinity and alkalinity in the soils hamper crop production which affect the country's economy. It has been estimated that approximately 8 million hectares of land (actual extent may be much larger) has been afflicted by this malady.

The importance of Indo-Gangetic alluvial plains to agriculture is immense. Therefore, the rate at which the soils are degrading (becoming saline and alkaline) is alarming and requires urgent measure to control and rectify this.

Aligarh lies on one of the worst affected 'Usar' belts of U.P., therefore, this part of the belt was selected for

detailed investigations, mainly, the mineralogical and geochemical aspects. Attempt has also been made to study the interaction between reh development and flora and fauna.

The area under study lies in the Ganga-Yamuna doab (inter-riverine). The soils in the area are mostly loam, sandy loam, silt to clayey in nature. The latter increasing with depth.

In the area around Aligarh, not less than 36,000 hectares of land, about 7 per cent of the total geographic area, is saline and another 7,000 hectares are on the brink of salinity and alkalinity.

The soils exhibit textural immaturity and occupy topographic troughs.

Among the minerals present in these soils, quartz is the most dominant and ubiquitous. It is followed by muscovite and feldspars. The heavy mineral assemblage comprise tourmaline, zircon, garnet, biotite, hornblende, chlorite, kyanite, staurolite, epidote and rutile indicating a Himalayan provenance of high grade metamorphic and some igneous and sedimentary rocks.

The relative scarcity of micas and feldspars indicate alteration to clay minerals. The soils of Aligarh do contain clay minerals, like, illite, chlorite, vermiculite, kaolinite. Calcite is a common constituent of the 'reh'.

In all the soil profiles studied, illite was found as a dominant clay mineral followed by chlorite, vermiculite and kaolinite.

The bulk chemical analyses of reh soils gave the range (per cent) for  $\text{SiO}_2$  as 40.38 to 62.65,  $\text{Al}_2\text{O}_3$  13.50 to 26.56,  $\text{Fe}_2\text{O}_3$  1.67 to 5.40,  $\text{TiO}_2$  0.19 to 0.89,  $\text{CaO}$  1.40 to 28.6,  $\text{MgO}$  0.40 to 13.10,  $\text{MnO}$  0.03 to 0.22,  $\text{K}_2\text{O}$  1.10 to 12.20,  $\text{Na}_2\text{O}$  0.20 to 5.80 and  $\text{P}_2\text{O}_5$  0.16 to 0.32.

Among the trace metals, the concentration of almost all the metals analysed, were found to be above safe limits as suggested by FWPCF (1968) and Ayers and Branson (1976). The range of the trace metals are given as follows alongwith their safe limits in parentheses :-

Ni	5-18 ppm	(2 ppm)
Cu	4-22 ppm	(5 ppm)
Zn	27-76 ppm	(10 ppm)
Pb	11-62 ppm	(10 ppm)
Cr	4-21 ppm	(1-20 ppm)

Cd is  $<1$  ppm, well within the safe limit.

It has also been observed that metal concentration in soils is also on the rise. This indicates that there are pollutional sources of contamination of metals. At Aligarh the large number of industries engaged in manufacturing locks, paints and pigments, and electroplating and also nearby Qasimpur Thermal Power Station, various hospitals, etc., discharge large amount of wastes which are taken up by soils, ground water and the rivers Ganga and Yamuna which carry them downstreams. The Yamuna and the Ganga are highly polluted

rivers in India which bring in large amount of pollutants from various big industrial cities upstreams and are the major source of soil pollution.

The soils at Tappal can be classified as highly saline-alkaline on the basis of pH, clay content, CEC, SAR, ESP and high  $\text{HCO}_3^-$  and  $\text{CO}_3^{2-}$ . The soils at Jawan, Panjipur and Sikandra Rao are alkaline or sodic instead of saline-alkaline, as suggested by others. The soils at Atrauli and Panhethi too are alkaline.

The soils at Aligarh are, in general, sandy to silty and clayey. The trough, topography, semi-arid condition, imperfect drainage, closeness of water table to surface and return irrigation water causes water-logging which results in the widespread efflorescence of salt, specially during the summer months. The underlying carbonate layer, on compaction, acts as a physical chemical barrier to percolating water causing stagnation and accumulation of Cr, Mn, Fe, Co, Ni, Zn, Pb, etc.

The plastered look and swelling and shrinking properties in these soils are due to the presence of illite, vermiculite and micas. The salt deposition is correlated to capillary action during dehydration, as observed by the deposition of salt crystals along the cracks.

The poor availability of plant nutrients is on account of non-survival of nitrogen-fixing bacteria under high pH, high sodium percentage and salt content. Thus a combination

of geological, climatic and hydrological factors are responsible in the 'reh' development at Aligarh.

Secondary salinization due to uncontrolled economic activity, rise in water-table and over-grazing is another cause of soil degradation. It is suggested that green manuring with rotational crop technique be adopted in order to raise the fertility status of the soil. Canal irrigation should be minimised, instead tube-well irrigation should be adopted in order to depress the rising water table. Plantation of Eucalyptus, Cynodan, Dhanicha, etc., should be encouraged followed by chemical reclamative measures.

Felling of forests in the Himalayan mountains where these rivers originate, should be immediately stopped so as to check erosion and supply of hazardous soluble salts, which are additional source of salinity and alkalinity in the Ganga basin.

With the opening of a number of headworks and canals in quick succession recently, a vast area of new land became water-logged causing widespread salinity in the canal command areas.

There is need to make an intelligent use of water as indiscriminate introduction of canal irrigation may cause excessive seepage, rise in water-table, widespread water-logging and increase in salinity. The success depends on how we take up that challenge and save our national heritage, the soil, from deterioration.



DEPARTMENT OF GEOLOGY  
ALIGARH MUSLIM UNIVERSITY.  
ALIGARH-202 001  
India.

*Noman Ghani*  
Reader

Dated 31.7.87

This is to certify that the thesis entitled,  
MINERALOGY AND GEOCHEMISTRY OF 'REH' SOIL IN SOME  
PARTS OF U.P.", submitted for the degree of DOCTOR  
OF PHILOSOPHY IN GEOLOGY is a faithful record of  
the bonafide research work carried out at the  
ALIGARH MUSLIM UNIVERSITY, ALIGARH, by MR. MOHD.  
AJMAL ANSARI under my guidance and supervision and  
that no part of it has been submitted for any other  
degree or diploma.

*Noman*  
( NOMAN GHANI )  
READER



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DEDICATED

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( MOHD. AJMAL ANSARI )

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## CHAPTER - I

### INTRODUCTION

#### 1.1. PURPOSE AND SCOPE OF WORK

The wealth of a nation lies in her soils. Its proper utilization, therefore, is very important. Consequently, various aspects of soils are being investigated intensively, particularly, geochemical, mineralogical and the phenomenon related to clay-organic interface. Presently the role of clays in the genesis of petroleum is considered very important. To begin with, study of mechanical properties, plastic fabric and topogeochemistry of soils is necessary before undertaking any detailed investigation.

Agriculture depends almost entirely on the quality of soils. In spite of two-fold rise in agricultural production of the world within the last 25 years, more than 500 million people still do not get adequate food. The conditions in India too are not very bright. In spite of fairly good soil in the alluvial tracts, abundant sun-shine, highest percentage of land under cultivation, ample water resources, etc., the average crop productivity is one of the lowest in the world. Among other causes an important factor is the continual degradation of the land. This can be best understood with the help of the following table.

**Table-1A : Land areas affected by various agents of soil degradation in India.**

Agents of Soil Degradation	Areas of Land affected
1- Water Erosion	90 million hectare
2- Wind Erosion	60 million hectare
3- Water logging	6 million hectare
4- Soil Salinity and alkalinity	8 million hectare
5- Shifting Cultivation	4 million hectare
6- River action, Mining, etc.	7 million hectare

It has been estimated that about 11 million hectare of tropical forest in the world and about 1.5 million hectares in India are lost annually. This has direct bearing with the reckless felling of forests and over-grazing of cattle in the river catchment areas.

Another factor is the opening of a number of head works and canals in quick succession to irrigate vast new areas. This causes water-logging in the canal command areas leading to wide-spread salinization and alkalization which results in low agricultural productivity. This also causes heavy toxic metal pollution. Proliferation of some technological operations and projects farther add to soil deterioration. Scientific

study of soils has thus become a priority item in arid and semi-arid regions.

The problem of salt efflorescence (salinization and alkalization) requires understanding of the nature of distribution and migration salts and elements within the soil profile. The topogeochemical behaviour (mineral-element-organic matter-salt-moisture regime-clay adsorption) of soils are closely related to climatic and hydrogeological conditions that prevailed at the time.

It is in this perspective that a research programme was drawn at Aligarh Muslim University, Aligarh, to study the mineralogy and geochemistry of 'Reh' soils of Aligarh and surrounding areas which are among the worst affected parts of the state of Uttar Pradesh. Field work was carried out during the months of May-June in 1985 and 1986. A large number of samples of soil were collected. Detailed laboratory studies was carried out on 30 soil samples collected at six selected profiling sites located in the water-logged areas.

## CHAPTER - II

### HISTORICAL 'RESUME', AGROCLIMATIC CONDITIONS AND REVIEW OF LITERATURE

#### 2.1. HISTORICAL 'RESUME'

Man is dependent on the soils and to a certain extent, soils are dependent on man. The quality of soils and the kind and quality of plants and animals grown on them determines man's standard.

The great ancient civilizations grew around great rivers like the Nile, the Tigris, the Euphrates, the Indus, the Yangtse, and the Hwang-Ho. This was made possible by the food producing capacities of the fertile soils of the river valleys civilizations. Periodic flooding of these soils replenished their fertility and provided continued abundant food supplies. It was not until man discovered the value of manures and crop residues that he was able to make extensive use of upland soils for sustained crop culture.

The downfall of some of the civilizations like Euphrates and Tigris due to soil degradation and mismanagement are historical realities.

Towards the end of 19th century, Barron Bertholett, one of the greatest luminaries of French science, accompanied Napoleon on his Egyptian expedition. He was struck by the

fact that solid sodium carbonate occurred on the banks of the Nile. Being one of the founders of Law of mass action, Berthollet believed that sodium carbonate was derived from calcium carbonate present in the soil.

Paul de Mondesir (1888) observed that calcium chloride, present in the aqueous extract of soil situated near sea, was formed by the action of sodium chloride on the soil. Subsequently, reaction with carbonic acid produce sodium carbonate.

The problem of salinization and alkalization in soils is universal among the normal (zonal) soils of arid regions of the earth. The saline-alkaline soils are estimated to comprise about 39 per cent of the world's dry land area. In Asia, they are wide-spread in the eastern and western Siberia, Mangolia, Manchuria, Persia, India, Afghanistan and Pakistan. Their prevalence in eastern part of Trans-Caucasia, Rumania, Hungary, United Kingdom, South-Eastern France, Australia, Western America, some provinces of Canada and North-East Central portion and South Africa is also recognised.

The distribution of the saline and alkaline areas are as follows (Fig. 1).

- 1- The coastal salt flats, Runn of Kutch.
- 2- Rajasthan and Madhya Pradesh.
- 3- The saline marshes of the sea-coast and the deltas of Ganga (Indo-Gangetic alluvial plain), Cauvery and Mahanadi.



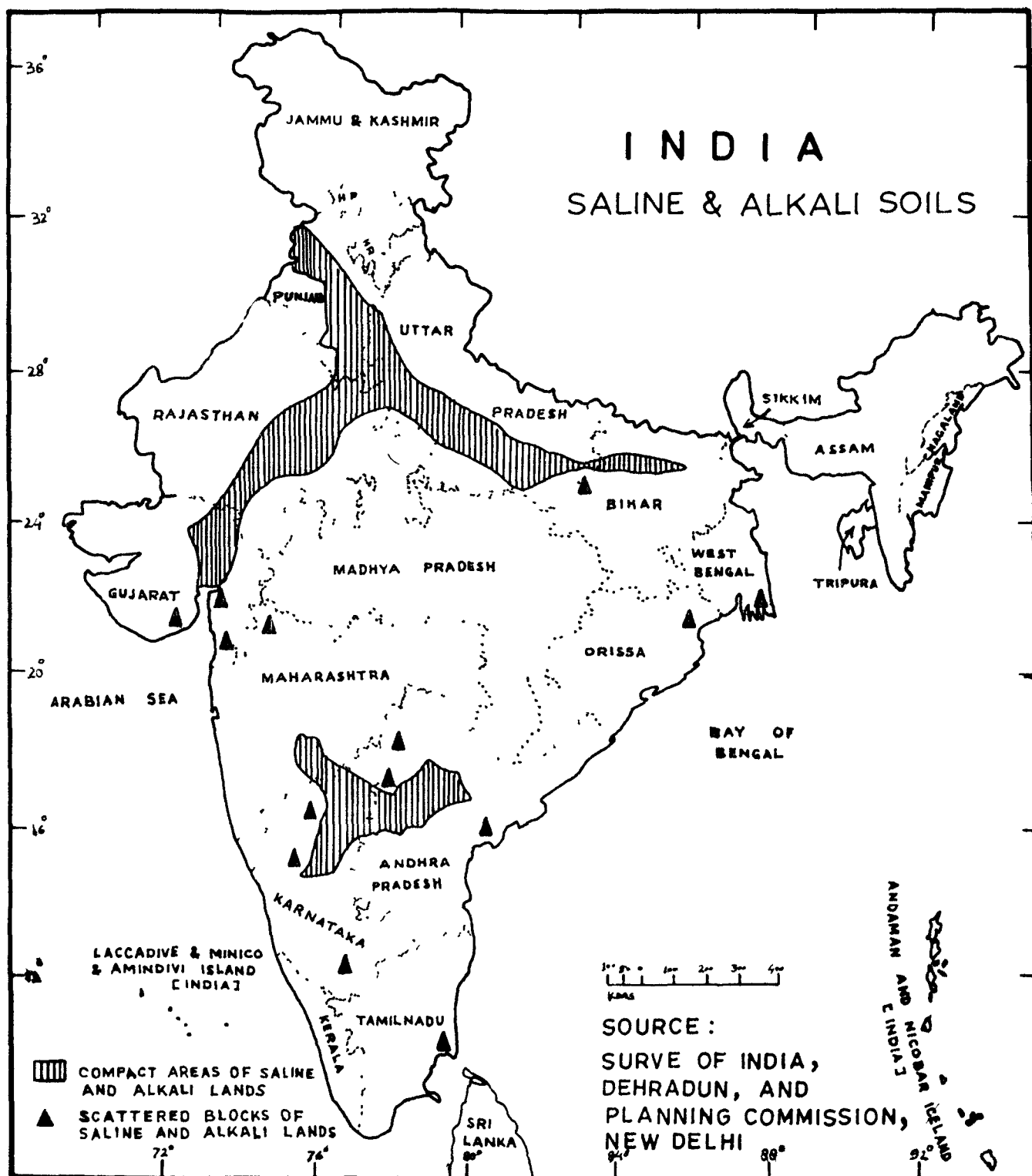


FIG.1

- 4- The uplands of Deccan plateau, especially between Godavari, Tapti and Bhima rivers.
- 5- The valley and basins of Western India.
- 6- The Indus valley.

As far back as 1877, a 'Reh Committee' was set up to investigate the causes of land deterioration in Aligarh district. Worth (1891) was, probably, the first to study in some detail the 'reh' soils of Aligarh district. He was followed by Leather (1893), Hill (1903), Auden et al. (1942), Agarwal and Mehrotra (1962), Raychaudhary (1962), Khan and Singhal (1968), Dutt (1968), Singhal and Akhtar (1978) and Singh (1978). While most workers studied the chemical aspects of these soils, Dutt carried out hydrological studies in these soils.

## 2.2. AGROCLIMATIC CONDITIONS

Aligarh is one of the fifty seven districts of Uttar Pradesh and is situated between 27°28' and 28°10' N Latitudes and 77°29' and 78°38' E Longitudes at an altitude of 187.4 m. It spans 116 km along East-West and 72 km along North-South. The area of the district is 5072 sq. km but varies slightly from year to year owing to changes in the course of the two bordering rivers, the Ganga and the Yamuna (Fig. 2). Aligarh has semi-arid and sub-tropical climate with hot dry summer and cold winters. The winter extends from the middle of October

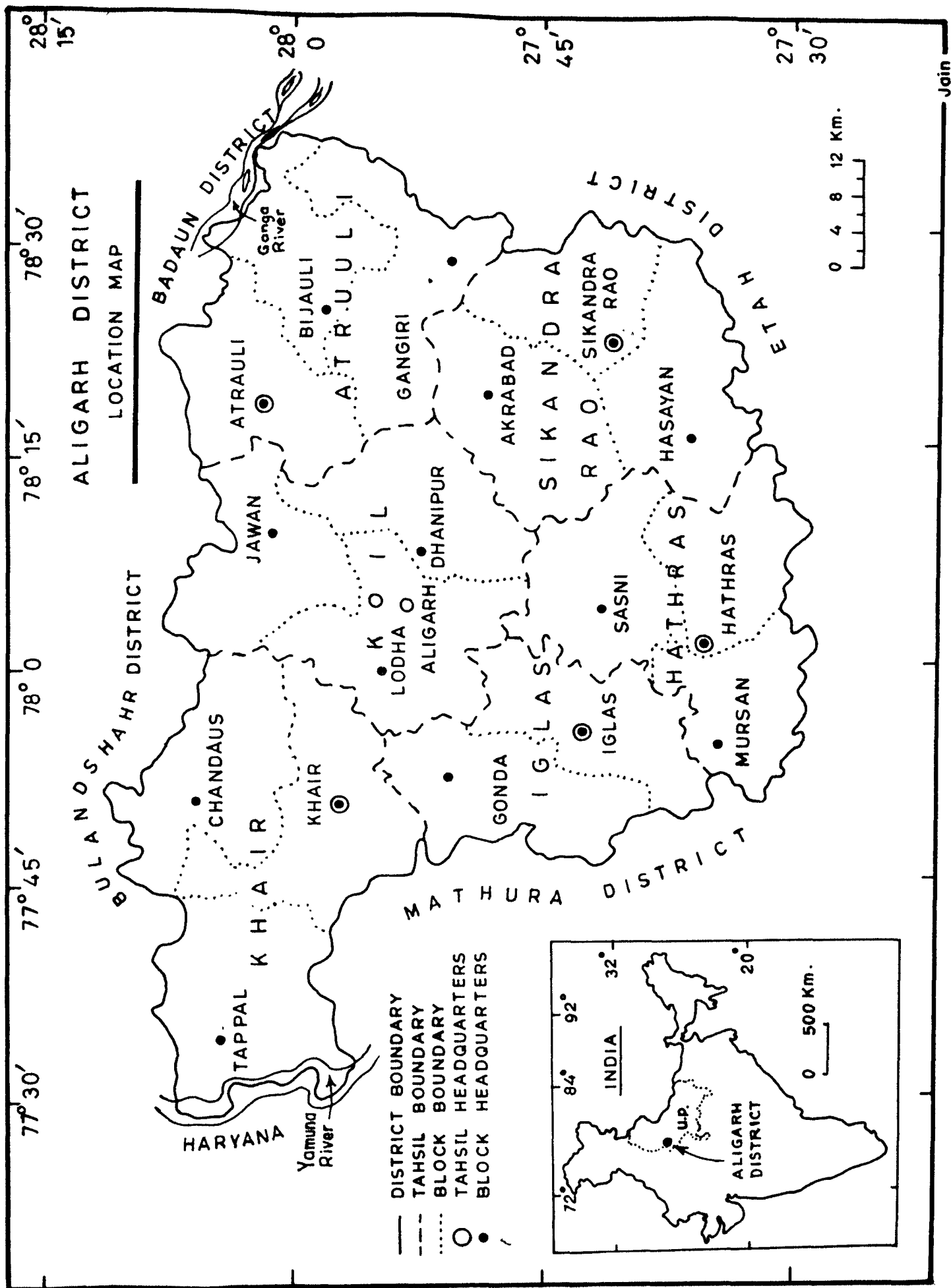


FIG-2

to the end of March. The mean temperature for December and January, the coldest months are about  $15^{\circ}\text{C}$  and  $13^{\circ}$  respectively and the extreme minimum record for any single day is  $2^{\circ}\text{C}$  and  $0.5^{\circ}\text{C}$  respectively.

The average temperature during May-June is  $34^{\circ}\text{C}$  whereas the extreme maximum record is  $47^{\circ}\text{C}$ . The average rainfall is 847.3 mm. But most of it (85%) occurs during June-September and only a little (10%) during the winter which is highly beneficial to 'Rabi crops'.

Aligarh and its surrounding areas are well connected with all-weather roads and railways.

### 2.3. REVIEW OF LITERATURE

The importance of pedogenic factors in the formation of soil was first recognised by Hilgard (1893) and later by Dockuchev (1898) who expressed it in the form of an equation in which factors like climate, organisms, parent material and time were included. Jenny (1941) included another factor of relief in addition to those given by Dockuchev. In later studies by Joffe (1949) and Rieckens (1965) emphasis was placed on the role of these factors under different environmental conditions. Subsequently, a factor of water table was also included in the soil formation (Crocker, 1952; Russel and Rhoades, 1956). Rode (1961) included eight factors in

writing his equation, the additional factor being gravity, water (surface, soil and ground) and man.

Soil genesis can be divided in two phases (i) the preparation and accumulation of soil materials through the agencies of weathering (Polynov, 1937; Henin, et al., 1953; Pedro, 1960) and (ii) the development of soil profile.

To account for different soil types, two initial states of soils can be considered - uniform and variable. (Karale, 1969; Tamhane and Karale, 1967). Factors like climate, topography, biologic and time are variable. Soil formation has been considered in terms of influence by individual factors. The pronounced influence of parent material (Ehrlich, 1955; Namjoshi, op. cit., Karale, op. cit., Mahjoory, 1979), drainage conditions (Gupta, 1952), climate (Sys, 1970 and Rao, 1977), biologic process (Williams, 1949), topography microgeomorphology (Govindarajan and Godse, 1972) and time (Gole and Hawley, 1968; Belzi and Closky, 1977; Ahmad, 1977; Rose et al., 1979).

Climate affects soils by controlling (i) physical and chemical reactions and (ii) organic factor and, to some extent and (iii) the relief. On this account bioclimatic regions have been a basis of classification of soils (Duggal, 1970). The soil variation in northern Indian plains have also been correlated with variation in rainfall (Shankarnarayana and Hirekerur, 1972; Sidhu, 1976).

The pedochemical studies conducted by Yadav (1977) on the soils of lower Vindhyan plateau in Mirzapur district (U.P.)

a well defined catenary relationship between drainage density and colour-texture variation down the slope. According to Prasad (1977) the soilscape at Junagarh (Gujarat) could be the result of both degradational and aggradational processes. The intermixing of soils obliterates the inherited characteristics from the parent rocks. Anand and Sehgal (1978) studied the relationship between profile development, soluble ions and chemical composition in alluvial soils of Indo-Gangetic plains. They reported that young soils contain greater amount of soluble ions and other chemical constituents in comparison to mature soils.

### 2.3.1. Soil Formation

The soil forming processes operative in the arid and semi-arid regions can be summed up as follows :-

According to Centre (1880) accumulation of salt in Indo-Gangetic basin is due to marine cycles through a sea gulf extending from Sind and Afghanistan in the west of Nainital in the East. Sediments were brought down from Himalayas through rivers to the gulf and a vast plain of alluvial deposits was gradually formed. The receding sea, however, left behind salines. The soil material rested on brakish acquifer. The salts in these soils, according to Leather (1897) can be (i) from a sub-soil salt bed, (ii)

deposited by river water alongwith alluvium (iii) in situ due to decomposition of minerals, and (iv) from canal water.

Aggarwal and Yadav (1954), Richards (1954) and Varallyay (1967) consider that the source of soluble salts in saline and alkali soils to be alumino-silicate minerals in the rocks. Thus a steady supply of bicarbonate and carbonate of the alkali will be available through surface and sub-terranean waters. These will get fixed in the undrained areas under arid climatic conditions (Kovda, 1964). Similar conclusions were arrived at by later workers (Pal et al., 1979; Bhumbra et al., 1980; Chaturvedi et al., 1981; Coyle et al., 1981; Bresler et al., 1981; Rao, 1986).

Egorov (1968) observed that the burried terraces in the piedmont plains of Alpine orogenic zone, showed high salinization in the soils at the lower part of each terrace. According to him, these were the residual soils when the ground water tables were high. Gwande and Tamhane (1970) reported that salt-affected soils of Leh area were derived from the alluvium of Indus river and colluvium of crystalline gneiss under cold continental desert climatic conditions.

In Afghanistan too, Aziz (1980) observed that crustal rocks were the original source of salt deposits. In dry regions, the released salts were carried only short distances and deposited in the valley soils, such as, those in the Helmand valley.

All deep mature soils of the Deccan region (India) have a zone of salt accumulation. High aridity and absence of leaching are the reasons ascribed to it. Auden et al. (1942) attributed salinity in the soils of U.P. to alternating wet and dry seasons. High rate of evaporation has been considered as one of the important factors in the accumulation of salt in soils (Sen, 1958; Bear, 1964; Kaushik and Shukla, 1977; Agarwal et al., 1979; Rose et al., 1979; Bresler, et al., 1982; Fitzpatrick, 1984).

Bhargava et al. (1980) concluded that the location of saline soil area in Haryana state coincide with the rainfall zone of 500-600 mm.

In low-lying areas, soils have higher contents of clay and silt with poor permeability. Obstructed drainage in such areas cause faster accumulation of salts in relation to other areas. This would account for high salinity in the soils of Aligarh, Mahi and Kadana project areas (Gujarat), Tungabhadra area (Karnataka and Andhra Pradesh) and Chambal command area (Rajasthan and Madhya Pradesh) (Bhumbla, 1977).

It has been noted that soils on slopes contain accumulations of salt and gypsum unlike those at the upper deviations (Maclean and Pawluk, 1975). Bhargava (1980) reported development of typical saline soil at an elevation of 227 m.

The non-saline or weakly-saline to saline soils transform into Solonchak due to uncontrolled irrigation. An inefficient



irrigation system would develop secondary salinization within a few years. The natric horizons in Sakit and Hasanpur Series might have come from basic material aided by salt rich ground water, poor drainage conditions, presence of impermeable 'kankar' pan and prolonged and uncontrolled canal irrigation (Gwande, et al., 1980).

The movement of materials in the soil, appropriately termed as 'pedotranslocation' (Mackeague and St. Armand, 1966), through infiltrated water in dissolved and suspended form, cause profile differentiation. Sehgal (1972) observed that clay migrated through soil when subjected to perfusion with water under slightly unsaturated conditions.

The dispersal of clay within the soil has been explained due to negative charge (Soil Survey Staff Rep., 1975). Such dispersed clay is believed to move with the percolating water and to stop where the water stops. Wetting of dry soil causes dispersion of clay, the cracks help gravitational water or water held at low tension to percolate. Water by capillary withdrawal is favoured by the strong tendency for a dry soil to take up moisture. Clay skins were reported to have formed in Wisconsin soils by deposition of clay carried down in suspension by percolating water from the upper part of solum (Buol and Hole, 1961). According to them the factors that enhance clay illuviation were time, relatively stable root channels, soil aggregates, adequate supply of clay and

percolating water. Goss et al. (1973) concluded that time and conditions of clay movement were functions of availability of clay and quality of precipitation. The formation of argillic horizons in the soils in Las cruces area is thought to be due to percolation of readily available water during Pleistocene period (Gile, 1966; Gile and Hawley, 1966; Ruhe, 1967; Gile and Grosman, 1968; Fitzpatrick, 1984).

Pedotranslocation of clays is a universally accepted phenomenon. Walker and Hutka (1977), state that in illuvial soils (B horizon) the proportion of fine to coarse clay increases with the advancement of pedogenesis.

The chemical processes associated with the reduction and mobilization of Fe and Mn and subsequent oxidation and precipitation are significant for estimating the soil moisture. Studies show that Mn compounds reduce before Fe compounds upon water logging of soils while reverse sequence applies upon aeration (Shelling, 1960; Bouma et al., 1969; Daniels et al., 1971; McKenzie, 1972; Bouma, 1972).

Simson and Boersma (1972), attributed reducing and oxidizing conditions as in Indo-Gangetic soils, to seasonally fluctuating ground water table or the intermittent presence of a perched water table.

The physical significance of soil mottling in terms of reduction and oxidation of iron and manganese compounds have been discussed by many workers. According to Veneman et al. (1976) anaerobic metabolic microbial action in nonaerated

saturated soils causes mobilization of iron and manganese compounds. Clothier et al. (1978) discussed a simple model of soil water drainage that aids interpretation of the pattern of mottling in a soil horizon above a coarse textured layer.

The most striking features of most of the zonal and some of the intrazonal soils in arid and semi-arid regions is the presence of a carbonate-enrich layer at the bottom of illuvial horizon.

Heath (1966) suggested the name 'kankar' for carbonate deposits. It was Bryan (1952) who first introduced the term 'nodule' for rounded irregular shaped mass. Sherman (1959) made an attempt to differentiate between concretions and nodules. The genesis of concretionary layers has been a subject of much discussion (Breazeale and Smith, 1930; Joffe, 1936; Bretz and Horberg, 1949; Brown, 1956; Harper, 1957; Roonwal, 1975; Awasthi and Chopra, 1981; Chaturvedi and Raymahashay, 1981; Wieder and Yallon, 1982). Hilgard (1910) recognised the importance of leaching of calcium carbonate which might accumulate in the sub-soil either as cementing material or around certain centres forming white concretions. Livingstone (1906) and Raman (1911) found that capillary rise of moisture made up soluble calcium carbonate to form layer of lime. Caliche appears to be characteristic of arid and semi-arid regions with alternate periods of wetting and drying. Caliche was thought to have formed by evaporation of ascending ground water as

well as by descending surface water, by plant roots removing water from calcium bicarbonate solution and by evaporation of surface and/or flood waters aided by algae and other plants (Jenny, 1941). According to Darrel et al. (1961), deposition of caliche in the soils of south-western Idaho, probably, resulted from soil forming processes.

The calcite in soils might have two possible origins, viz., 'primary', inherited from the parent rock, and 'secondary', formed in the soil itself. Sehgal and Stoops (1972) considered that calcite in Indo-Gangetic alluvium was of secondary origin. Roonwal (1975) too concurred with this view.

Alternate dry and wet seasons in semi-arid regions would account for calcitic nodules, often surrounded by neoferous material formed under to reducing condtion (Shegal and Stoops, 1972). The carbonates of alkaline earth have been explained due to pluvial activity (Dhir, 1976). Thus the presence of alkaline earths in soils suggest a seasonally wet but an overall dry climate.

It has been observed that saline-alkali soils of Karnal are characterized by a zone of calcium carbonate (nodules) whereas the normal soils were very low in carbonates (Sen, 1953; Kanwar and Sehgal, 1962; Raychaudhury, 1963). The high  $\text{CaCO}_3$  observed in the lower layers of most salt-affected soils of Kaira district (Gujarat) could possibly be due to displacement of calcium from the upper layers to lower layers (Pathak and Patel, 1980).

Since there is a good correlation between soil types and topography, aerial photographs from Landsat imagery have been used to demarcate salt affected soils of Haryana and other areas (Manchanda et al., 1983; 1984; Ahuja et al., 1985).

Mineralogical study of various types of soils of India was undertaken like red lateritic soils (Raychaudhury and Mukherjee, 1942), black cotton soils (Tamhane and Namjoshi, 1959), some soils of M.P. (Gwande, et al., 1963), some soils of Chhotanagpur of Bihar (Sinha and Mandal, 1963) and some soils of Rajasthan (Singh and Bhandari, 1964).

Roy (1954) reported epidote, hornblende, garnet, kyanite, zircon, mica and tourmaline among the heavies and mostly feldspar among the light fractions from the soils of Delhi and Karnal.

The ratio of light to heavy fractions may be used as a measure of degree of weathering (Ruhe, 1956). The soils of Bihar are reported to contain greater amount of easily weatherable minerals (Sinha and Manda, 1963). The soils of north Gujarat contain more resistant minerals, such as, zircon, garnet and tourmaline indicating transported nature of soil (Barde and Goworkar, 1965). Roonwal et al., (1967) investigated the fine sand fraction of the soils of Hissar district and reported biotite, chlorite, epidote, garnet, sphene, zircon, tourmaline and iron oxides among the heavies and quartz, muscovite and feldspar among the light minerals. They concluded

that these are drift soils derived from sedimentary or para-metamorphic areas of Himalayas. Singh (1974) reported amphiboles in addition to above. The soils at Aligarh were reported to contain quartz, calcite, mica, biotite and some dark brown particles of ferruginous and manganiferous material (Singhal and Akhtar, 1973).

The subsurface alluvium of Lucknow contains quartz (dominant), garnet, epidote, hornblende, kyanite, tourmaline, apatite, zircon and chlorite probably of metamorphic and granitic provenance of Himalayas (Singh, 1975).

The soils from Punjab, Pundeer (1978) is reported to contain quartz and muscovite as dominant light minerals and biotite, tourmaline, garnet, kyanite and sphene as the major heavy minerals. Thus a dominant metamorphic and subsiding acid igneous source areas are suggested.

Sehgal (1973) reported that the dominant mineral association in salt-affected soils of Sangrur (Punjab) was hornblende-epidote and garnet with occasional parametamorphic mineral. Manchanda (1978, 1982) reported the predominance of quartz followed by muscovite and with calcite. The mineralogical composition of clays in soils depend on weathering. There is a predominance of illite and kaolinite in the saline alkali 'Reh' soils of Lucknow (Raychaudhary, 1952-53), of kaolinite in the soils derived from granites and pegmatites and of illite from those derived from slates and shales (Mukherjee,

1958), of illite and montmorillonite in the soils of the lower Gangetic basin (Gupta, 1961), of illite and chlorite from the soils of western U.P. (Gupta, 1968; Khan and Singhal, 1968; Chatterjee and Gupta, 1970) and of illite, chlorite and kaolinite in soils of Aligarh district (Jadava and Gupta, 1972; Ghani and Ansari, 1984; Ansari, 1984). Yadav and Gupta (1974) have also reported smectite from moderately alkaline soils of U.P. Raman and coworkers (1975) reported the occurrence of illite, chlorite, vermiculite, smectite and traces of kaolinite from some soils of U.P. Bhargava (1981) reported illite, smectite, vermiculite and chlorite from the soils of Haryana. Inter-stratification of illite-chlorite and illite-vermiculite is common in the salt affected soils of India (Kapoor et al., 1981). Chlorite, smectite, kaolinite and mixed layer minerals are reported from the soils of Jammu (Gupta, et al., 1986). The alkaline soils of Gujarat are reported to contain mainly smectite followed by vermiculite, chlorite, mica, kaolinite and allophane among the clay minerals (Kaswala and Deshpande, 1986). According to Rhoades (1976), clay minerals exert considerable influence on the salinity and fertility of soils.

### 2.3.2. Soil Nutrients and Amendments

The modern concept of soil fertility is based on the capacity of the soil to buffer the ionic environment against

changes in ion activity caused by nutrient removal. The capacity of soil to release potassium from the non-exchangeable form is a function of micaceous clay fractions (Mulford and Jackson, 1966). Feldspar, micas, and K-bearing minerals play important role, in this respect. Joshi et al. (1982) observed that low potassium fixation is due to higher K-saturation.

Since  $\text{SiO}_4$  and  $\text{PO}_4$  tetrahedra are interchangeable, the phosphate fixing ability of acid and alkali soils of Punjab were attributed to free sesquioxides. The finer soil fraction contributes significantly towards forms and availability of phosphorus (John and Gardner, 1971).

Sodic soils are deficient in both soluble and exchangeable calcium. Plants grown in sodic soils die more often from lack of Ca than from toxic effects of Na. The availability of Ca depend upon soil ESP, root CEC and plant species (Poonia and Bhumbla, 1972). The wide-spread occurrence of calcium related physiological disorders, in fruits have also been reported (Bangerth, 1979; Loughheed et al., 1979).

The observed 'zinc deficiency' in salt affected soils is due to low organic content and high pH and  $\text{CaCO}_3$  (Bhumbla and Dhungra, 1964; Kanwar and Randhawa, 1974; Misra and Pandey, 1976; Katyal et al., 1980). The heavy metal cations - copper, cobalt and zinc are susceptible to exchange reactions with clays (Jone, 1936), with copper bound more strongly than zinc (Peech, 1941). Similar behaviour has been reported for cobalt (Zende, 1954).



The available nitrogen in sodic soils decrease with increasing pH (Paliwal and Maliwal, 1975) and depth (Laura, 1973). High pH and increased pollution cause micro-organism, including nitrogen-fixing bacteria, to die as a result nitrogen is not available to the plants (Bhardwaj, 1975; Akhtar, Ansari and Khan, 1983).

An excess of certain ions, like,  $\text{Cl}^-$ ,  $\text{SO}_4^{2+}$ ,  $\text{HCO}_3^-$ ,  $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  and, occasionally,  $\text{NO}_3^-$  and  $\text{K}^+$  may make soils toxic to plants. Carter and Myers (1963) found that  $\text{NaCl}$ ,  $\text{CaCl}_2$  and  $\text{Na}_2\text{SO}_4$  inhibited the production of chlorophyll and carotene in the leaves of grape fruit.

Miyamoto (1977) proposed addition of sulphuric acid (a waste by-product in many industrial areas) to irrigation water to check precipitation of  $\text{CaCO}_3$  in the root zone.

Reclaiming saline and sodic soils is a challenging problem. Carter and Fanning (1964) compared ponded leaching with periodic applications of small quantities of water by sprinkling. They (1964 and 1965) applied surface mulches to reduce evaporation at the soil surface and to enhance infiltration. Benz et al. (1967) found that straw mulches effectively reduced evaporation from dry land-cropped soil.

Gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) has been utilized for many years with varying success as a source of  $\text{Ca}^{2+}$  to replace  $\text{Na}^+$  from the soil. Oster and Frenkel (1980) suggested that gypsum requisite for sodic, calcareous suits be increased by a factor

of 1.1 to 1.3 depending upon the final exchangeable sodium percentage desired.

In India, the Ganges basin is the largest, densely populated, fertile and intensively irrigated grain bowl of India. But it is beset with serious pollutional problems. There is a progressive increase in pH, salinity, alkalinity and heavy metal contamination. No systematic data on pollution is available for the soils of Aligarh.

## CHAPTER - III

### MATERIALS AND METHODS

The characteristics of soils show wide lateral variation, therefore demarcation of soil types on the map poses a host of problems. Also there is no generally acceptable method of sampling. Any method chosen is essentially need-based.

#### 3.1. APPLICATION OF REMOTE SENSING TECHNIQUE FOR SOIL STUDIES

The application of MSS data in the natural resources studies grew after the launching of LANDSAT-1 in 1972, then known as ERTS (Earth Resources Technology Satellites) and, subsequently, with the availability of more spaceborne data from other satellites of the LANDSAT series, their application in soil science grew manifold. The first major study in soil engineering was made at the Purdue University, U.S.A., for recognition of soils and their parent materials. Further developments in the technique for pedological analysis was developed at I.T.C., the Netherlands. The matter involved continuous imaging in different spectral bands, of vast and remote areas. Every object on the terrain emits or reflects electromagnetic energy at specific and distinctive wave lengths producing a characteristic pattern or spectral 'signature' for it. Identification of soils involved studying its tonal response

in several spectral bands. However, the pattern of a particular soil holds good only for a specific area in a specific season due to various influencing factors. The MSS data is usually analysed employing either visual or computer method. In general, False Colour Composite (FCC) provides maximum information about soils. The validity of interpretation, however, is influenced by factors like reference level of the interpreter and facility of deduction.

In India, Krishnamurthy and Srinivasan (1973), prepared small-scale maps of some soil areas from the Apollo and Gemini photographs. This led to effective use of Landsat data for soil mapping. The maps so prepared showed much better delineation so far.

Landsat data used in conjunction with air photos and ground truth provide a high degree of accuracy in demarcating and monitoring of salt affected soils, as at Aligarh.

The following Landsat MSS imagery were used for mapping the soils of Aligarh and surrounding areas :-

LANDSAT : satellite 1, 2

Imagery Numbers : 157-40 and 157-41

Bands : MSS scene of bands 4, 5 and 7, and F.C.C.

Years of Imagery : 1972, 1981

Names of Agencies : NRSA (India) and NASA (U.S.A.) (Plate-1).

The following toposheets and maps were also used for mapping :-

PLATE 1

Landsat imagery of the study area showing white patches of the 'Reh' in the soil. Note the distribution of patches alongside the major streams, in low-lying areas.

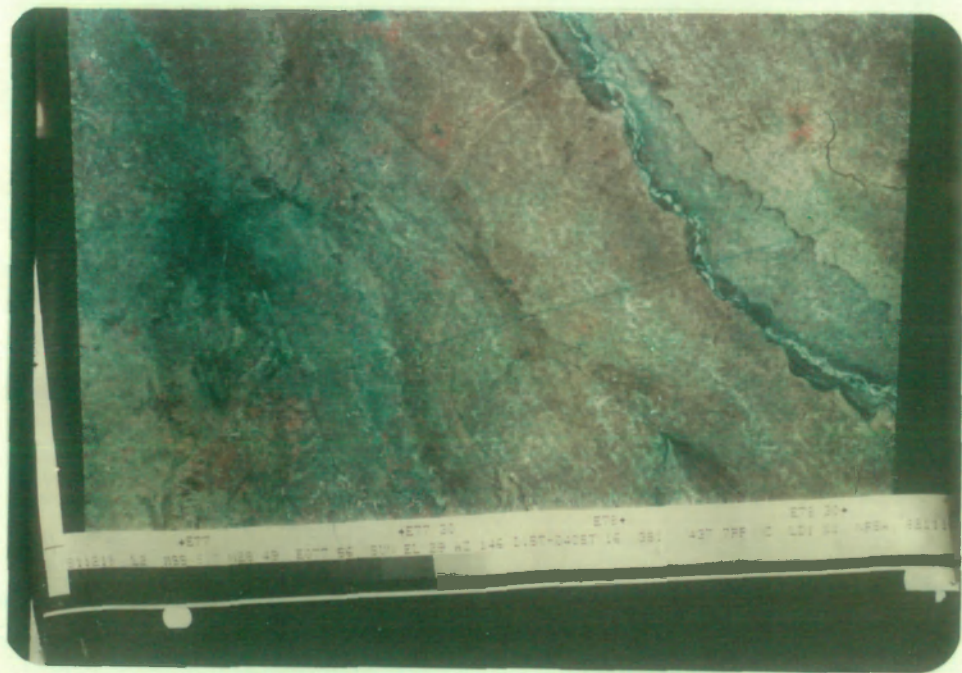


PLATE 1

- 1- Survey of India toposheet nos. 53 H/16, 53 I/3, 53 I/8, 53 L/8, 53 L/12, 54 E/13, 54 E/14, 54 I/1, 54 I/2, 54 I/15 and 54 I/16 on 1 : 50,000 scale.
- 2- Soil maps, Soil Testing Lab., Aligarh (U.P.) (1982).

The multiband imagery were analysed and mapped on 1 : 250,000 and 1 : 10,00,000 scales. The image characteristics were also found useful in interpreting physiography, moisture content etc., of soils.

### 3.2. FIELD WORK

The field work involved :-

- 1- Mapping of major 'Reh' or 'Usar' patches on 1 : 25,000 scale.
- 2- Profiling of the soils to obtain the following information:-
  - i. Agricultural utility
  - ii. Soil development factor functioning
  - iii. Sequence of mineral weathering functionality.

A number of sites were selected for profiling in Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao areas (Map 2). The soils were excavated about 1.5 to 2 meters deep during the warm periods of April-May in 1985 and 1986. Various soil horizons were differentiated on the basis of variation in texture, colour, mottling, calcareousness, hardness, root contents, etc. Field observations were recorded according to

the guidelines of FAO (1966) and USDA (Handbook No. 60, 1968).

3- Sampling :- Samples of soils of approximately 1.5" x 1.5" x 1.5" size were collected for preparing thin sections as suggested by Fitzpatrick (1984). About 2 kg of bulk samples were collected at each site for mineral separation and chemical analysis. The samples were collected in polythene bags and labelled properly with field cards placed inside. The bags were left open in the laboratory to allow the samples to dry at room temperature.

### 3.3. PREPARATION OF SAMPLES

The air-dried samples were weighed, crushed and broken to about 2 mm size first with a roller and then with rubber pestle in agate mortar. The crushed samples were passed through (i) 2 mm sieve for the study of physical properties, and (ii) 0.5 mm sieve for use in chemical analysis. The calcium carbonate concretions, left out on the sieves, were collected, washed, weighed and ground separately for chemical and mineralogical studies.

#### 3.3.1. Mechanical Analysis

The mechanical analysis of soil fractions was carried out using International Pipette method (Piper, 1950). Separation



of fractions was carried out by dry sieving method using up to 30 mesh size (0.05 mm).

### 3.3.2. Separation of heavy and light minerals fractions

About 5 gm of sample (0.177-0.149 mm size) was taken and light and heavy mineral fractions were separated using bromoform (sp. gr. 2.89) as heavy liquid. The heavy and light residue so obtained were washed, dried, and weighed separately.

Mounting :

Permanent mounts of heavy and light mineral fractions were prepared on glass slides using Canada balsam as mounting medium.

### 3.4. THIN SECTION OF SOIL

Thin sections were prepared from the soil blocks according to Fitzpatrick's method (1984) though with a slight modification. The following is the detail of the method :-

Blocks of soil were first immersed in xylene to remove air for about 3 to 5 minutes. Some quantity of Canada balsam was melted in a tin container on a hot plate and then the blocks were immersed in it for impregnation. The impregnated

soil blocks transferred to a glass slide taking care to avoid trapping air bubbles. It was then left for two days at room temperature. The hardened block was very gently cut with a fine hacksaw to avoid any rupture taking place. Thus about 2-3 mm thick slice was obtained on the glass slide. Final grinding was done using a paste of fine carborundum powder in liquid paraffin. Care is taken to avoid using, coarse carborundum powder for grinding as this may cause grains to come out. Final grinding was carried out very gently using a flat cork.

#### 3.4.1. Carbonate Staining

For the identification of calcite and dolomite uncovered thin sections were stained according to the method given by Dickson (1965). Two solutions were prepared, one of 2.0% alizarin red-S in 1.5% hydrochloric acid and the other of 2.0% potassium ferricyanide in 1.5% hydrochloric acid. The two solutions were then mixed in the ratio of 3 : 2. The thin section slides were placed in this solution in a bath for 30-45 seconds. The slides were then immediately washed with distilled water in a beaker and, after drying, covered with a cover glass. Under the microscope calcite takes red stain while the dolomite remains unstained.

### 3.4.2. Thin Section of Kankars

Thin sections of kankars were prepared in the same manner that of rocks except that carborundum paste was prepared in liquid paraffin instead of water.

### 3.5. PREPARATION OF SAMPLES FOR SEM STUDIES

Samples were first reduced to fragments about 1.5 cm long by chipping with scalpel to expose fresh fractured surfaces. They were mounted on alumina stubs using normal glue. After air-drying for 3-4 hours, the base of the material was painted with a suspension of silver colloid in methyl-isobutyl ketone solution. The samples were then coated with thin gold and palladium layers a few tens of angstroms thick using a sputtererror. The samples so mounted were studied on the SEM (Model Cambridge Stereo Scann S-4-10).

### 3.6. PREPARATION OF SAMPLES FOR X-RAY DIFFRACTION STUDIES

X-ray studies were necessary for identification of clays and clay minerals. For this, two types of samples were prepared - oriented and random.

### 3.6.1. Oriented Samples

The clay samples, oriented on basal planes, were prepared by the method of Hein and Gutanacher (1972) of U.S.G.S. Taking 15 gms of sample, the carbonates and organic matter were removed by placing it in 50 ml water and adding 10 ml  $H_2O_2$  and 10 ml. Margon's solution, keeping it stirring till the bubbling ceased. This was left for two days to allow it to settle down. It was then centrifuged at 1000-1500 rpm for about five minutes. The concentrates at the bottom were washed first with distilled water and then with 2%  $Na_2CO_3$  solution. Thereafter, the sediments were suspended in 0.01%  $Na_2CO_3$  solution and again centrifuged for 3 minutes at 850 rpm. By this method sand and silt would settle down at the bottom leaving suspended matter with diameter  $2\ \mu$  or less. The latter were then collected in separate bottles and centrifuged again till the supernatant became clear (i.e. no more clay is in suspension). The residue thus obtained contains pure clay.

The pure clay mixed with water was evenly spread over glass slide and left to dry at room temperature. This allows clay particles to settle down on the basal plane. The layer now appear translucent. Two slides of each sample were thus prepared. Final drying of slides was done in dessicators.

The diffractogram of the samples were obtained for CuK $\alpha$  radium for scan between  $2^\circ\theta$  and  $33^\circ\theta$  (on the Philips X-ray Unit). 36 KV and 18 MA setting, chart speed  $1^\circ/\text{min}$  and

2 $\theta$  speed 2°/mm. The X-ray unit used was Philips Model U.K. Three diffractograms of each sample were obtained as natural, glycolated and heated. Glycolation was done by treating the sampler slides with glycol followed by dessication. This causes expansion in the lattice of some clay minerals. Heating was done in an electric furnace for about 1 hour at 550°C followed by cooling in a dessicator in moisture-free atmosphere.

The 2 $\theta$  values, read directly from diffractograms, were converted into interplanar spacings (d Å) with the help of Bragg equation.

$$n\lambda = 2d \sin\theta$$

where n = order of reflection

$\lambda$  = X-ray wave length

d = Interplanar spacing

$\theta$  = Bragg angle

Conversion tables for Cu targets was used to get the d-values directly.

### 3.6.2. Random (unoriented) samples

The soil samples were first dried in oven at 115°C for 2 hours, passed through a 320 mesh sieve and packed in aluminum sample holders. They were then lightly pressed down on a glass plate, inverted right side up, to obtain a flat and fine

surface. Scanning was carried out between  $2^{\circ}\theta$  to  $33^{\circ}\theta$  for identification of clay and carbonate minerals.

### 3.7. CHEMICAL PARAMETERS

The pH and electrical conductivity were measured with the help of a CTC portable kit CT-105. A 1 : 2 soil water suspension was used for this purpose.

#### 3.7.1. Organic Carbon

Organic carbon was determined employing the rapid titration method of Walkley and Blacks (1949).

#### 3.7.2. Saturation Extract

For obtaining saturation extract, the methods described in the USDA Handbook no. 60 were followed.

#### 3.7.3. Soluble Cations

Sodium and potassium were determined by Flame photometry on the Flame Photometers of Systronics and Toshniwal (India) make.

Calcium and magnesium were determined using Versenate method given by Cheng and Bray (USDA Handbook no. 60, 1968).

#### 3.7.4. Soluble Anions

The methods of USDA (Handbook no. 60) were used for the determining carbonate, bicarbonate and chloride.

#### 3.8. CHEMICAL ANALYSIS OF MAJOR AND TRACE ELEMENTS

The CaO and MgO were determined by titrimetric method (Bear, 1965).

SiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> were determined on UV spectrophotometer (Katz, 1968). Other major element oxides (MnO, TiO<sub>2</sub>, Fe<sub>2</sub>O<sub>3</sub>) and trace elements (Ca, Co, Ni, Cd, Cr, Li, Pb, Zn) were determined by Atomic Absorption Spectrophotometer of Pye-Unicam make.

## CHAPTER - IV

GEOLOGICAL EVOLUTION OF UTTAR PRADESH, TOPOGRAPHY,  
DRAINAGE, SOIL TYPES, GEOLOGY OF ALIGARH AND SURR-  
ROUNDING AREAS, INCIDENCE OF REH SOILS IN U.P.,  
INCIDENCE OF REH IN ALIGARH DISTRICT4.1. GEOLOGICAL EVOLUTION OF UTTAR PRADESH

The State of Uttar Pradesh (Latitude  $23^{\circ}52'$  N to  $31^{\circ}28'$  N and  $77^{\circ}4'$  E and  $84^{\circ}38'$  E Longitude), is the most populous state of India, and is unique in various respects in the entire subcontinent. The state represents almost entire Indian stratigraphic column. Right from Archean (Bundelkhand gneissic complex), Palaeozoic (Kumaun-Garhwal and Bundelkhand), Mesozoic (Kumaun-Garhwal, partly in Lalitpur district), Tertiary (Kumaun-Garhwal) up to Recent (the Indo-Gangetic alluvial plains) all formations are found.

A large part of the vast shallow Vindhyan Basin possibly extended up to the Lesser Himalayas with several cycles of chemical and clastic sedimentation. A part of Gondwana basin (Singrauli coalfield), was developed in faulted troughs in the southern table-land.

The Himalayan province, is divided into four physiographic-lithotectonic units :- (i) The Outer Himalaya comprising fluvial and lacustrine deposits of the Siwalik Supergroup (Middle



# GEOLOGICAL EVOLUTION OF UTTAR PRADESH

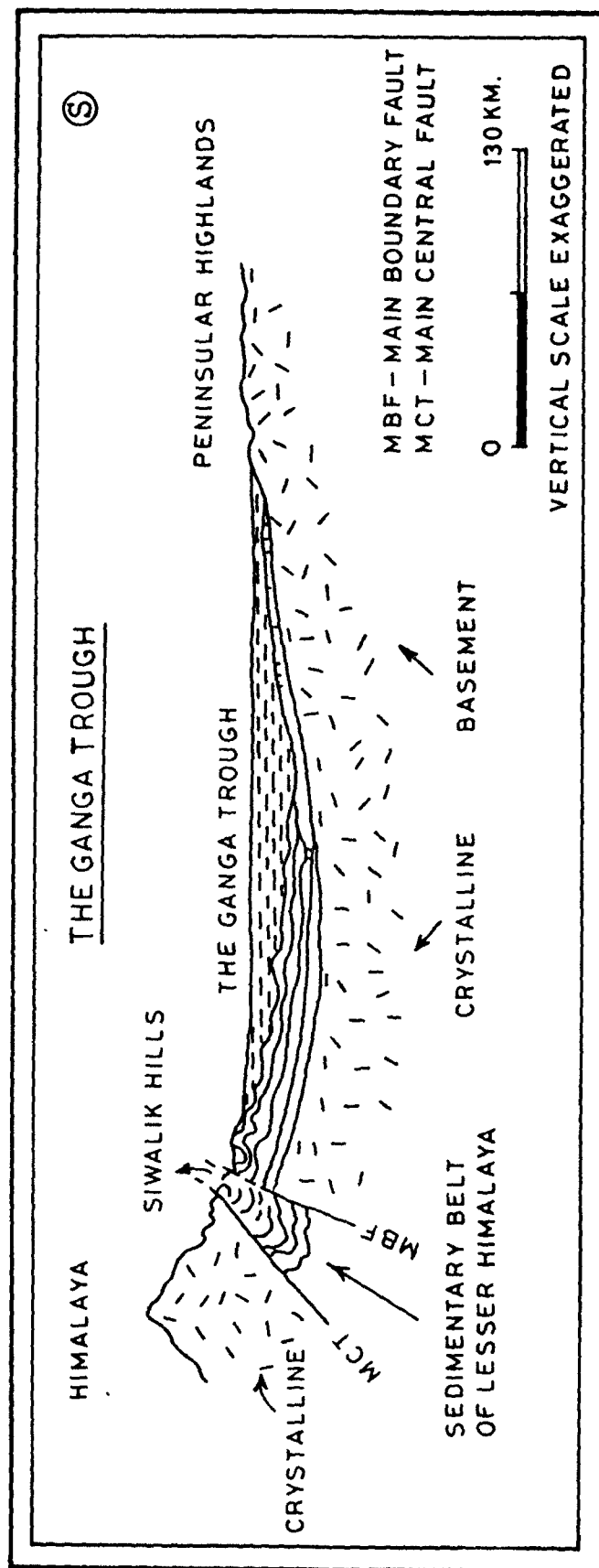


FIG. 3 . DIAGRAMMATIC REPRESENTATION OF THE GANGA TROUGH SHOWING THE MAIN BASIN BETWEEN THE PENINSULAR HIGHLANDS IN SOUTH AND THE HIMALAYAN REGION IN NORTH . EXTENSION OF THE PENINSULAR AND THE HIMALAYAN SEDIMENTARY FORMATIONS CAN BE SEEN BELOW THE ALLUVIUM .

Miocene-Pliocene age), (ii) The Lesser Himalaya comprising massive pile of highly folded and faulted sedimentary strata (Precambrian and Palaeozoic age), (iii) The Greater Himalaya, comprising crystalline axis of the mighty mountain chain, with enormous pile (10-12 km) of meso-to Kata-grade schists and gneisses with younger intrusives, and (iv) The Tethys Himalaya comprising fossiliferous sediments (Algonkian to Lower Eocene age). The Ganga Basin occupies the central part of the state.

#### 4.1.1. The Ganga Basin

The Indo-Gangetic plain represents a great depression related to deep fracture within the sub-crust and is not merely synclinal fore-deep (Fig. 3). It has a sedimentary cover of more than 25000 ft. in the northern part.

Aeromagnetic survey (1962, 1964) of the basin revealed three prominent faults - Moradabad, Lucknow and Patna whereas basement ridges divide it into four sectors.

Fuloria (1969) recognised eight major lithostratigraphic units within the basin and postulated the presence of marine Mesozoic and Paleogene sequence.

#### 4.1.2. Structural Framework

Along the western margin of the basin there is a sub-surface fault striking NE-SW. It is in continuation with the

'Great Boundary Fault' of Rajasthan which separates Aravallis from Vindhyanas. The tectonic boundary, probably, extends up to Kalka and Simla in the west. The Monghyr-Saharsa ridge of the Satpura Orogenic belt demarcates the eastern boundary of the basin.

Along the northern boundary is the Himalayan Frontal Fault with folded Siwalik sub-province in the north. The southern margin of the Gangetic plane is bordered by the table-land of Bundelkhand massif and Vindhyan basin.

The major tectonic boundaries are controlled by the major basement lineaments, configuration and the thickness of the alluvium (Fig. 4). The peninsular orogenic belts, such as, Satpura, Aravalli and Delhi, continue along the basement with shelves and depressions progressively deepening northwards. They were filled up with Vindhyan and Paleogene sediments.

There are two cycles of sedimentation separated by an angular unconformity. The older cycle comprises siltstone, metasandstone and limestone-orthoquartzite-shale association while the younger cycle comprise alluvial sands, silts and clays. In a deep well at Ujhani, rocks below unconformity were encountered at a depth of 2062 m. They have been dated at 1040-1045 ma (Precambrian age). Their age and lithology are similar to those of Vindhyanas.

# UPPER AND MIDDLE GANGA PLAIN BASEMENT STRUCTURE AND DEPTHS AIRBORNE MAGNETOMETER SURVEY-AGOCs (1956)

## LEGEND

- SIWALIK, DHARMSALA (DAGSHAI AND KASAUJI) GROUPS AND SUBATHU FORMATION (TERTIARY)
- DECCAN TRAP (CRETACEOUS-EOCENE)
- RAJMAHAL TRAP (JURASSIC-UPPRECRET)
- VINHYANS (? LOWER CAMBRIAN)
- DELHI / ARAVALI (ARCHAEAN-ALGONKIAN)
- ARCHAEAN GRANITES / UNCLASSIFIED CRYSTALLINES
- FAULTS
- GONDWANA (CARBONIFEROUS-JURASSIC)
- ~5000' BASEMENT DEPTH IN FEET

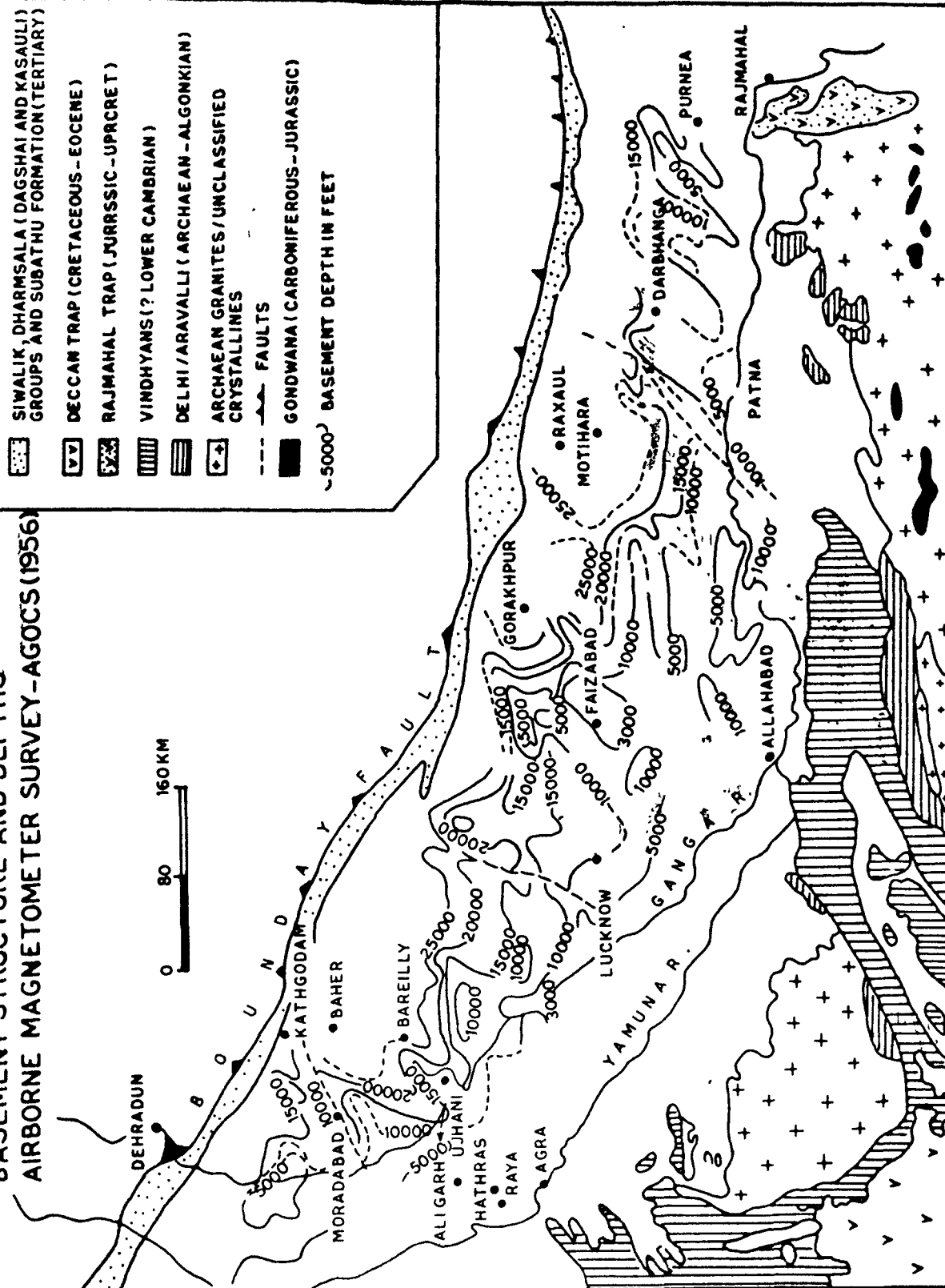


FIG. 4

#### 4.1.3. Geology and Geomorphology of Indo-Gangetic Plain

Aligarh is situated in the Ganga-Yamuna 'doab' (Inter-reverine) of the Great Indo-Gangetic plains. In the foothills of the Siwalik range Siwalik sediments end and older alluvium extend southward up to the foothills of the Aravallis, Vindhyan and the Bundelkhand massif. The Older Alluvium, generally, form some high terraces are found above the flood level. They also show some 'caliche' or 'kankar' composed of carbonate of lime developed in them.

The Newer Alluvium are the Recent pluvial/fluviol sediments deposited over the eroded surface of the Older Alluvium. They consist of gravels, sand and sandy clays near the river channels and silt at the flatter parts and the deltas.

The upper Ganga plain, has more or less uniform topography. The soils, largely homogeneous, have some Usar patches roughly located along belts roughly parallel to river coarses.

#### 4.2. TOPOGRAPHY, DRAINAGE, SOIL TYPES AND GEOLOGY OF ALIGARH AND SURROUNDING AREAS

##### 4.2.1. Topography

The topography is generally flat. The alluvial plain is drained by the rivers Ganga in the north-east and Yamuna in the

||



**FIG- 5**

north-west (Fig. 5), with a gentle slope towards south and south-east. The homogeneity is broken at Iglas, Khair and some western parts by sand ridges alternating with depressions. The level rises from the low Yamuna flood plains in the west towards the centre and then descends eastward into a slight depression formed by Kali Nadi. Farther east, the land again rises and merges into the Ganga flood plains.

The highest and the lowest elevations in the area are 640 ft. above M.S.L. in the northwest 2622 fts. above M.S.L. in the south, respectively.

#### 4.2.2. Drainage System

The drainage system is an important feature of the Aligarh landscape (Fig. 6). The Kali Nadi is the only important line of natural drainage while the Ganga and the Yamuna barely touch the periphery of the study area. There are also a number of small seasonal streams like Neam, Karon, Sengar and Rind.

#### The Ganga

Ganga takes a south-easterly course along the northern boundary of Aligarh district. There is a belt of recent 'khadar' alluvium along the course of the river, which, during rainy seasons, shifts from one side to another over a belt of 5 to

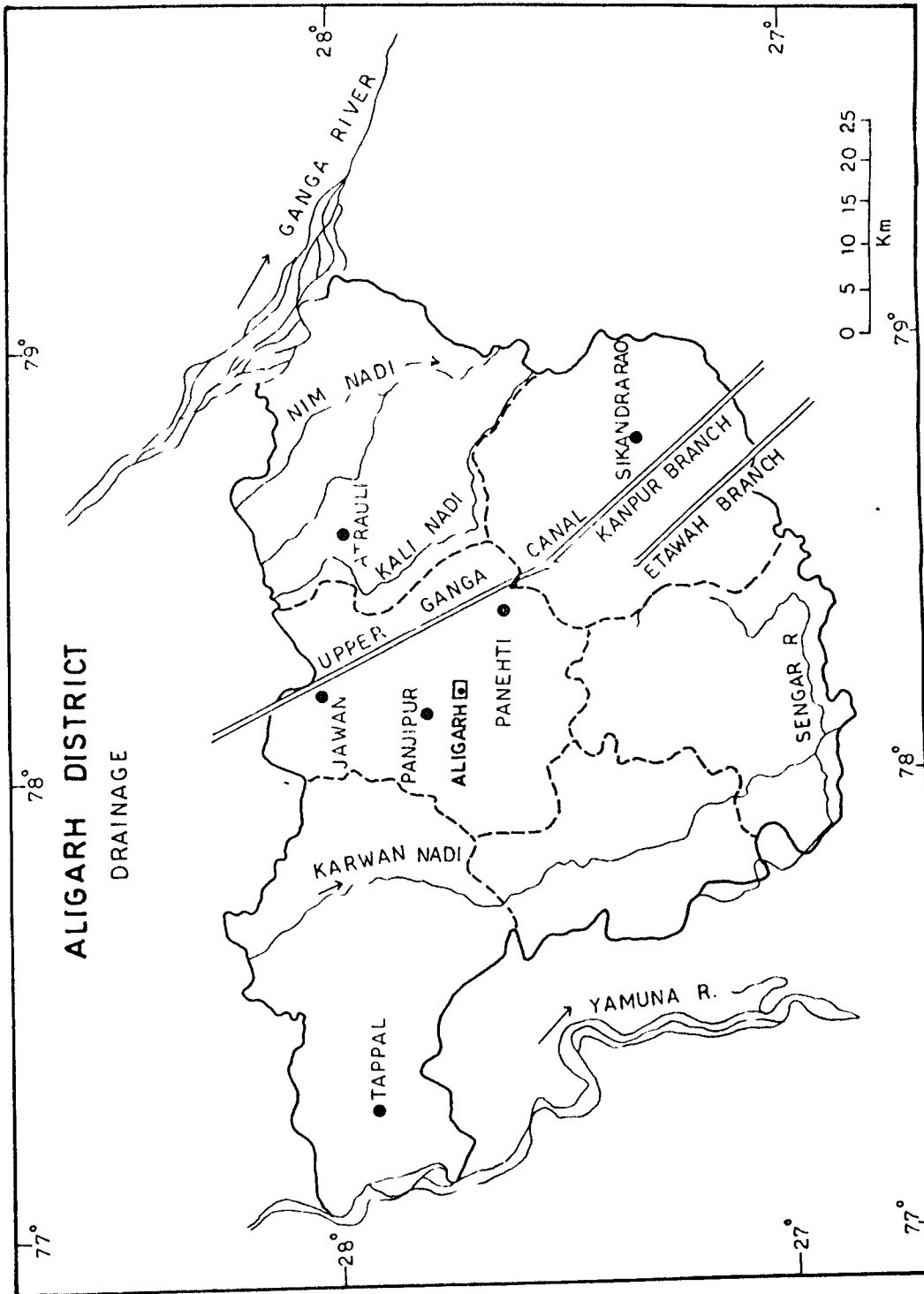


FIG-6



6 kms. This has been remedied partly by constructing a lower Ganga canal at Narora. The areas along the river are very fertile but remain water-logged during the floods.

#### The Yamuna

An important tributary of the Ganga, Yamuna flows towards south making a minor loop. The adjacent lands are, generally, flat, low-lying plains with gentle slope. Its span varies from about 390 m during the rainy season to about 150 m in summer months. Similarly, the velocity of flow also varies from about 11 km/hour during rainy season to 3 km/hour at other times. The river banks are very fertile.

#### Kali Nadi

Kali Nadi, also called as Kalindri has southerly course. It is perennial, with narrow valleys, markedly high banks and variable span. It is joined by Neem Nadi on its left bank.

#### Karon Nadi

Karon Nadi, also called as Karwan, is a seasonal stream which flows from north to south through Khair, Iglas, and Hathras taking a south-east course before joining the Yamuna

near Agra city. In its upper course it has a broad basin with a good deal of low ground on either sides.

#### Neem Nadi

Neem Nadi is another small seasonal stream and is a tributary of Kali Nadi. Its bed has been deepened further to improve the drainage and its water is used for irrigation purposes.

#### Sengar Nadi

Sengar is a tributary of Yamuna. Its origin can be traced to the great Adhwa Jhil of the central depression. It flows southwards and then takes a turn towards Hathras. The river also transports a good amount of water from a large artificial drain cut at Lehtoi. It is a seasonal river.

#### Rind Nadi

Rind Nadi or Arind is another seasonal river originating at the central low lands between two branches of Ganga canal. It flows southward in the south-easterly direction.

#### 4.3. SOIL TYPES

The soils of Aligarh are alluvial and have been divided geologically, into two broad subdivisions :- (i) Khadar, newer alluvium and (ii) Bhangar, older alluvium. They bear several local names and new names are assigned for even slight variation in the properties.

**Khadar Soils :-** The Khadar soils are relatively rich in plant nutrients, occupying narrow siltation tracts of rivers and their tributaries. They are deficient in organic matters, specially, phosphorus. They have immature profiles with sandy to silty-loam texture. Devoid of concretions, they have a fair proportion of lime and other soluble salts and are neutral to alkaline ( $\text{pH} > 8$ ). The Yamuna Khadar soils, however, have submature profile abundant clays and concretions and very high lime and other soluble salts.

These are related to poor drainage system. The Trans-Yamuna Khadar differs in having a relatively mature profile, with average lime content. Their texture is loamy. Frequent siltation adds to their fertility.

**Bhangar Soils :-** Extensive in areal spread, Bhangar soils occur in inter-fluvial zones. Their profiles are somewhat mature and have variable colours. Soluble salts and lime

are, generally, low and show neutral reaction in low lying areas which are prone to water-logging. Illuviation is common throughout.

According to a survey of Aligarh district, six types of soils were recognised (U.P. Agriculture Department, 1951).

The are :-

- |                      |                           |          |
|----------------------|---------------------------|----------|
| (1) Aligarh Type I   | Ganga Khadar              |          |
| (2) Aligarh Type II  | Eastern uplands           |          |
| (3) Aligarh Type III | Centra' lowlands          |          |
| (4) Aligarh Type IV  | Western uplands           |          |
| (5) Aligarh Type V   | Trans-Yamuna (stiff loam) |          |
| (6) Aligarh Type VI  | Yamuna Khadar             | (Fig. 7) |

#### (1) Aligarh Type-I Soil - Ganga Khadar

Ganga Khadar soils are recent alluvial deposits brought in by the Ganga during rainy season. They occupy a long narrow belt. They are sandy to silty with loam texture and colour varying from light grey to ash grey.

The Ganga Khadir areas have imperfect drainage with little lateral or downward movement of ground water resulting in springs within one to two meters of the surface. This causes wide-spread salt efflorescence on the surface, specially, during the summer months. Their pH is above 8.

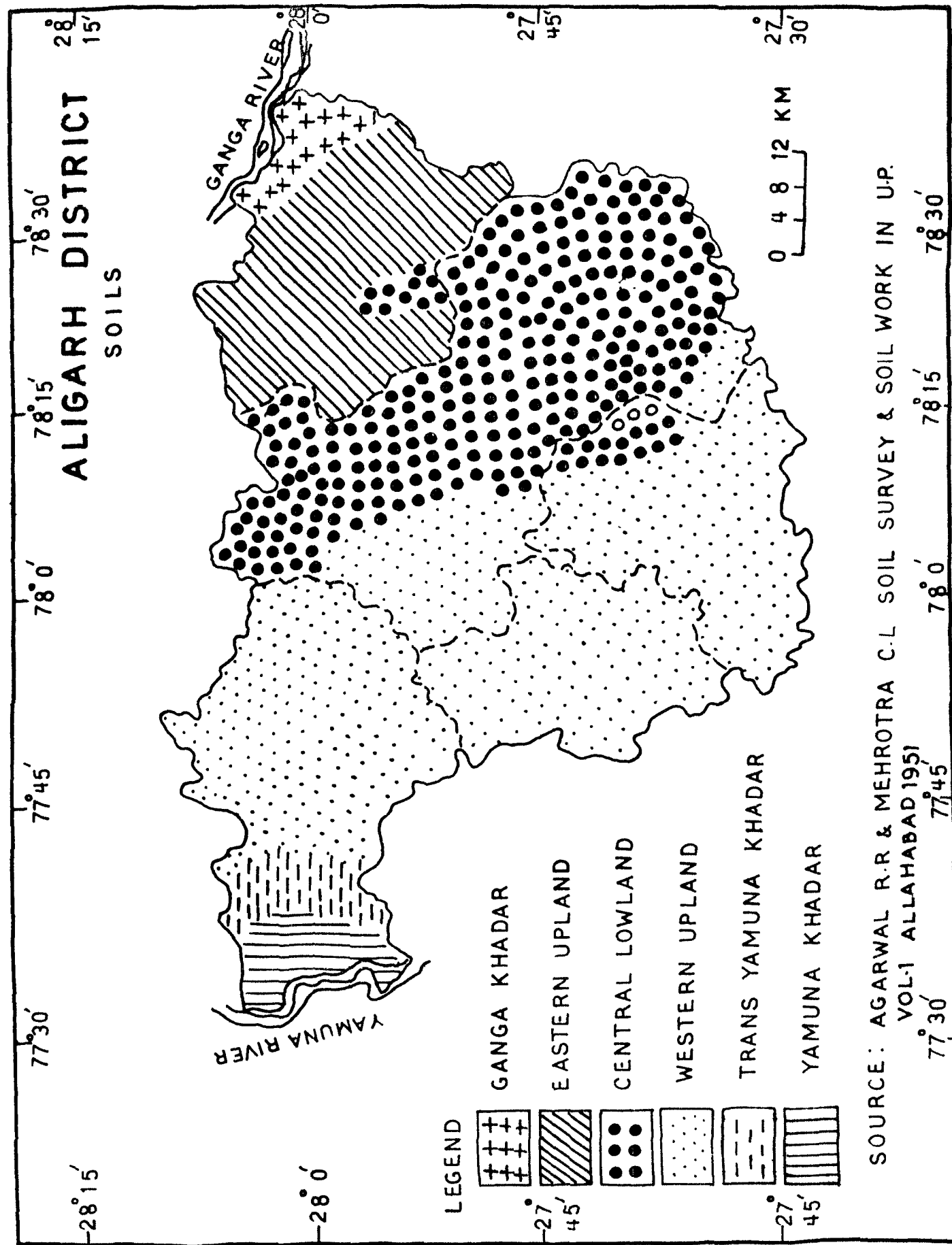


FIG-7

## (2) Aligarh Type II Soil - Eastern Uplands

The Eastern uplands soils are found around Atrauli bearing a narrow depression in the south and a thin belt of Ganga Khadir in the north-eastern part. The surface soil is light brown to reddish in colour. The sub-soil is dark coloured. Texturally, they are sandy loam to loam. The surface soil, up to 25 cm, being well drained, is loamy and can be easily cultivated. They show higher degree of leaching than those found at other places. The lime is low but magnesia is high. Iron nodules occur almost everywhere in the sub-soil. The saline efflorescence is insignificant.

## (3) Aligarh Type III Soil - Central Lowlands

The central lowlands soils occupy the eastern part of the area beyond G.T. Road up to Sikandra Rao covering the central low lying tract. It forms a north-south belt, parallel to the course of Ganga. The drainage is poor. Abundant jhils and swamps dot the area indicating water-logging. The soils are, generally, sticky in nature. They are from clayey-loam to clayey in texture and have colour varying from grey, ash grey to dark grey and black when moist. Generally, there is an underlying layer of kankar made up of nodules which, at places, cement together forming a stiff impenetrable layer.

These kankar rocks are very often used as building material. The clay content decreases with distance due to sub-soil horizon being unimpregnable. The sodium salts deposited on the surface form 'rer'. During hot season it presents a sight of white salt-infested land. Southward an alkaline low magnesia soil, locally called 'chicknot', occurs.

#### (4) Aligarh Type IV Soil - Western Uplands

Locally known as 'bhur' these cover the largest area on the map, occupying the upland, which includes the tehsils of Iglas, Hathras, western part of Koil and almost 75 per cent of Khair. It extends from G.T. Road in the east to the Patwaha nala in the west except the Karwan valley which has a very narrow strip of stiffer soil. The area is artificially drained by a 'Ganda nala', joined in by numerous natural and artificial drainage lanes. Large scale development of Usar is significantly absent.

They have sandy texture, brown to reddish brown colour and low calcium clay content due to leaching. Soil erosion is indicated by ridges.

#### (5) Aligarh Type V Soil - Trans-Yamuna Khadar (Stiff Loam)

A narrow (9 km wide) belt of trans-Yamuna Khadar soils,

is roughly parallel to the Yamuna Khadar on the eastern side of the river. Occupying flat regions as stiff loamy soil, they merge with the ridges of bhur in the south. The texture of these soils vary from good quality loam to sandy loam but remain slightly stiff. The clay content is greater in the middle sub-soil than those in the top and bottom layers. The bottom layers are more sandy (78% sand) and finely textured. The colour of the top soil is ash-grey and that of the sub-soil rather dark. They are more compact with abundant kankar nodules, specially in the top and the bottom layers. The water retaining capacity of these soils is poor. The organic matter and nitrogen content is average. The iron content increases with depth. Leaching raises alkalinity in the bottom soils. Magnesia is more abundant than lime. The percentage of soluble salt is not very high. The dominant salts of bicarbonates are concentrated mainly in the top layers decreasing, gradually, with depth. These soils have a good exchange status but the calcium saturation is rather low.

#### (6) Aligarh Type VI Soil - Yamuna Khadar

The Yamuna Khadar forms a sandy tract along the extreme north-western part with width varying from 9.65 km in the north to about 3.2 km in the south along the river beds of the Ganga. These get over-flooded when Yamuna is in spate.



The soils are sandy to silty loam in texture. Though relatively poorer in sand they are richer in clay than the other types of soils. The soils are rather hard and difficult to till, especially, when dry. When wet, they get puddled up. The ground water-table is unusually near the surface and during the monsoon months it remains virtually on the surface itself. The soils are alkaline with pH, usually, 8. The alkalinity and bad physical characters render the soils unfit for normal agricultural use. The soils have sufficient lime but magnesia exceeds the lime except in the bottom layers, which are sodimised. The sulphates are higher in the surface layer but deeper down carbonates ~~inc-~~ increase.

#### 4.4. GEOLOGY OF ALIGARH AREA

Lying between Himalayas and Peninsular India, the area forms a part of the Sindhu-Ganga alluvial plain located in the Ganga-Yamuna 'doab' (inter-riverine). The alluvium is of Quaternary age. They form the largest alluvial plain in the world. It represents a rapidly sinking basin with sediments deposited almost exclusively under the fluvial conditions. The alluvium was brought from the Himalayan ranges by the Ganga river system (Dutt, 1968; Singh, 1975). The deposition started with the uplift of Siwaliks during the Middle Pliocene-Pleistocene period.

The alluvium at Aligarh consists chiefly of the various grades of sand, silt and clay. Beds of very coarse sand and gravel are, generally, uncommon. Also associated with fine grained strata are the kankar (calcium carbonate) zones of secondary origin. A generalised succession of soil horizons is as follows :-

379.36 meters	Surface clay
	Clay with fine sand and kankar
	Sand, fine to medium gray (micaceous)
	Clay, yellow with kankar
	Kankar mixed with yellow clay
	Clay yellow with kankar
	Gravels (siliceous kankar with yellow clay)
	Gravels calcareous
	Gravels with yellow clay
	Gravels calcareous with fine sand
	Clay yellow with Gravels
	Clay, sand with kankar
	Sand, fine to medium with quartz gravels and very little clay
	Sand medium with gravels and clay
	Clay sand with red calcareous clay
	Clay red
	Vindhyan Red shales with malachite encrustations (Fig. 8)

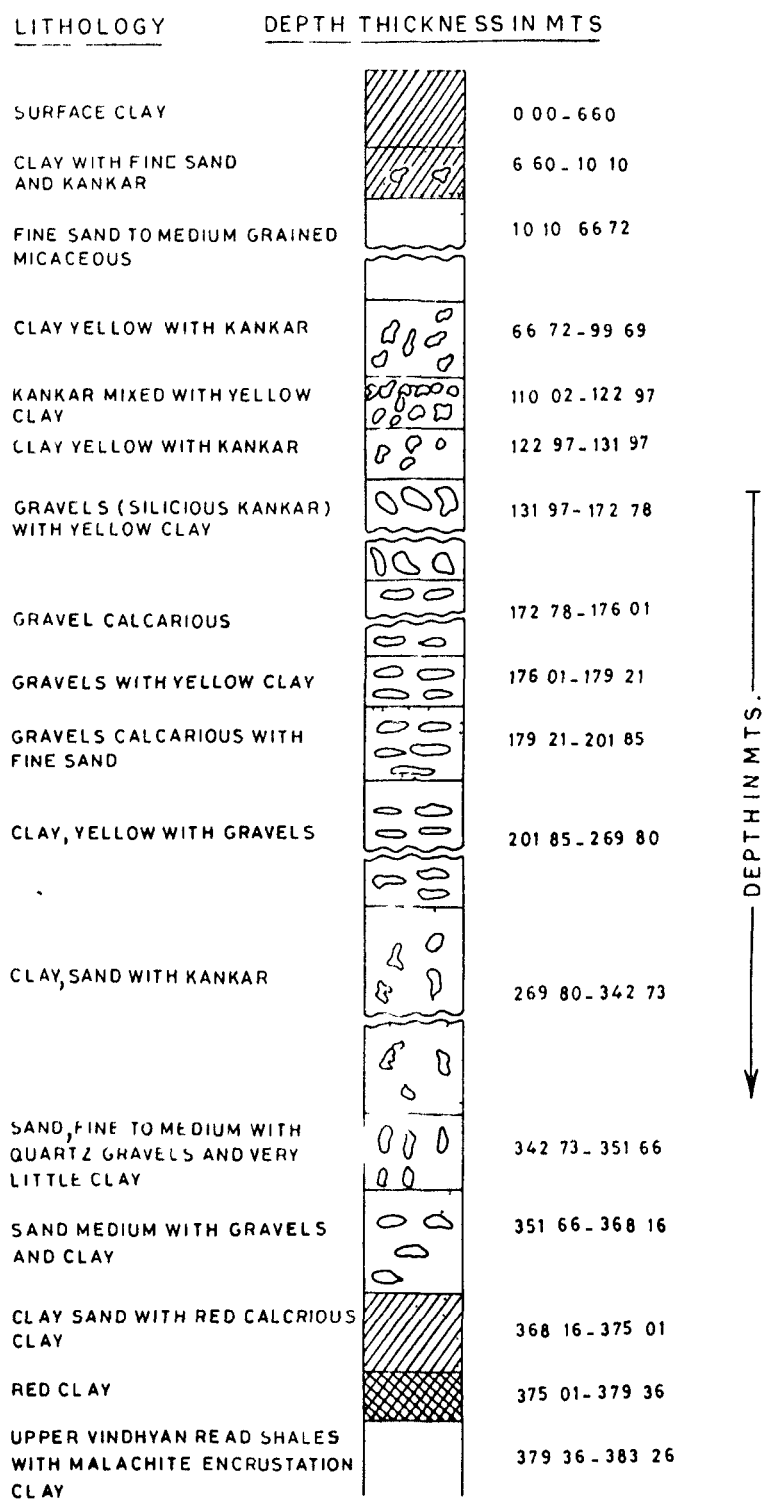


FIG 8 LITHOLOGICAL LOGS SHOWING GENERALISED GEOLOGY AT ALIGARH RAILWAY STATION DRILLING DONE ON 16 6 76 - 25 6 76

SOURCE C G W B LUCKNOW (U P)

According to Eduard Suess, the great Austrian geologist, the plain represents a 'fore-deep' in front of the resistant mass of the Peninsula when the Tethyan sediments were thrust southward and compressed against them. Thus, this 'fore-deep' was the remnant of the sea of Tethys, out of which the Himalayas were uplifted. This depression was, gradually, filled up by the sediments brought down by the Himalayan rivers in the north and Peninsular rivers in the south. This view was supported by Misra (1981).

Burrard (1921), on the basis of physical and geodetic considerations, concluded that Indo-Gangetic plains occupy a 'rift-valley' formed due to sinking of a portion of the earth's surface with pari passu deposition. According to him the sub-crustal crack or rift extended from surface far down into the crust (32 km), which was subsequently filled up by the alluvium. Burrard's views are not in full agreement with the geological observations. Most geologists view Indo-Gangetic depression as a true fore-deep, a downwarp of the Himalayan foreland of variable depths, thrusting into flat plains by alluviations. According to geologists, vigorous deposition of sediments and consequent depression gave rise to this vast tectonic trough.

A third, relatively recent view, invokes a sag in the crust in the north of the drifting Indian subcontinent. The crumpling and uplifting of the sediments accumulated in the

Tethyan sea gave rise to a mountain system. Once formed, the depression was filled with sediments brought down by the rivers from Himalayas and Peninsular India.

Regarding the age of formation, it is believed, that the Indo-Gangetic depression must have come into existence during the later stages of Himalayan orogeny. The depression, probably, began to form in the Upper Eocene and attained its maximum during the third upheaval in the Middle Miocene. Since then the sediments filled it gradually forming a level plain with a very gentle seaward slope. The broad uniformity of detritus suggests a subsiding trough since the Pleistocene times. Continuous uplift of the Himalayan mountains would rejuvenate the young streams, thereby, increasing their carrying capacity. This would lead to rapid filling of the depression during Middle-Pleistocene to Recent. Oldham on the basis of geological observations, estimated maximum depth of the trough to be about 4,600 meters near its northern limit from where the floor rises up to its southern edge where it merges with the Vindhyan uplands of the Deccan.

The gravity, magnetic and seismic surveys of the Indo-Gangetic plains suggest thickness of the alluvial cover ranging from 1000 m to 2000 meters. Glennie (1932), on the basis of geodetic observations estimated a thickness of about 1950 meters. His earlier (1921) estimation gave a value of more than 3000 meters.

The magnetic surveys reveal a number of local 'highs' and 'lows', all of which slope steeply towards the north. A number of borings done for artesian wells up to a depth of 1606 meters. In 130 borings carried out for ground water surveys the depth at which the bed rock was encountered ranged widely between 100 meters to 400 meters.

Aero-magnetic surveys gave the depth of basement rocks at about 7000 meters and the geophysical data gave a depth of 6000-7500 meters.

The data collected by the Geological Survey of India for Bihar region shows that the thickness varies from 1800 meters to less than 3000 meters.

During the 1976 drilling operation by the Central Ground Water Board at the Aligarh railway station, red Sirbu shales of Upper Vindhyan age were encountered at 379.36 meters below the ground level (Fig. 8).

Thus there is no unanimity regarding the origin and thickness of the Indo-Gangetic alluvial deposits.

#### 4.5. INCIDENCE OF 'REH' OR 'USAR' IN UTTAR PRADESH

In ancient India (2500 BC), salt-affected soils were referred to as 'usar' or 'reh' meaning salt (Raychaudhari and Govindarajan, 1970). All such soils were later classified as Solonchak or Solonetz in the U.S.S.R., the U.S.A. and India

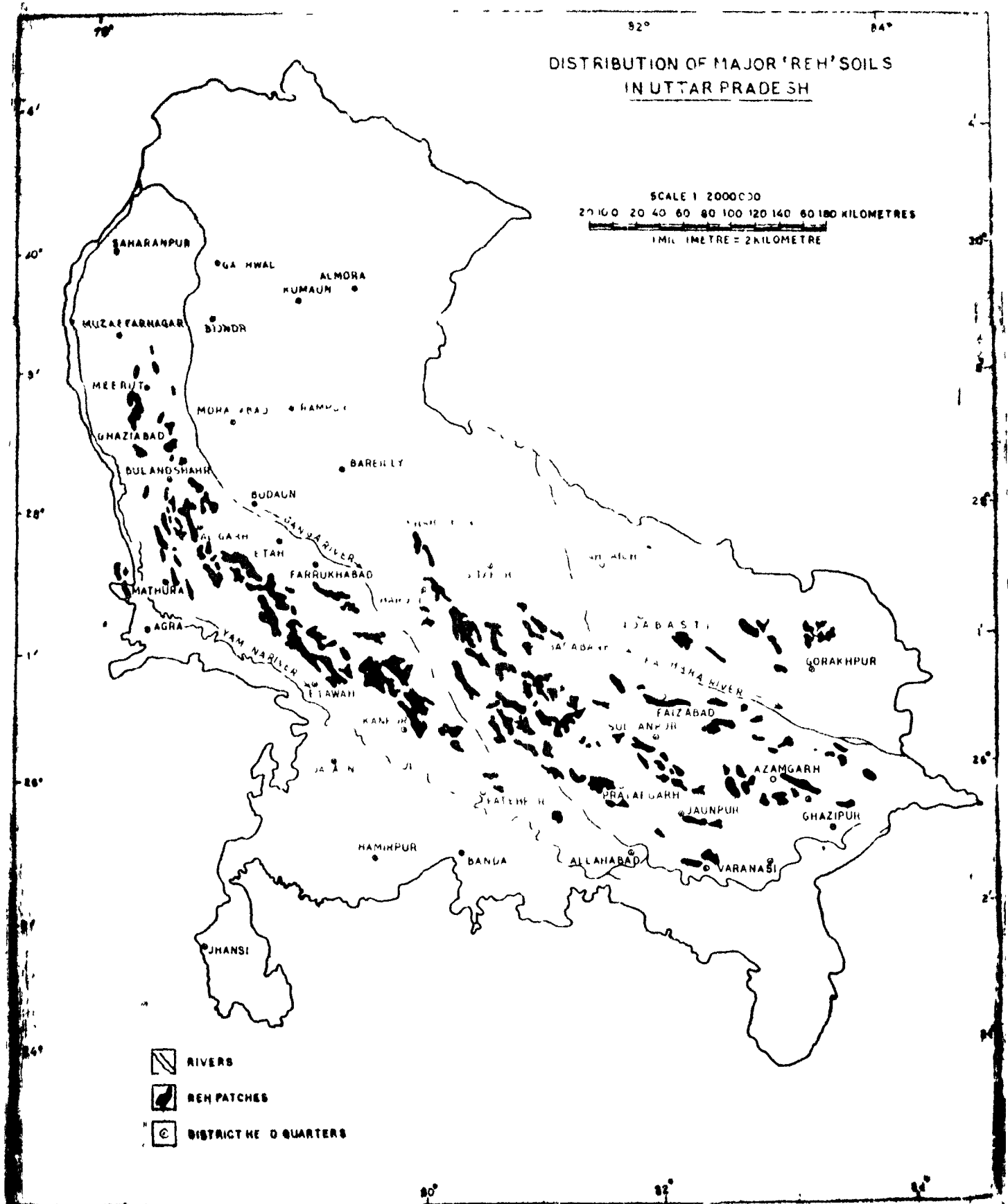


FIG-9

(Venkataramiah, 1941; Raychaudhuri and Tripathi, 1953; and Raychaudhuri and Sinha, 1957). According to Richards (1954), saline, sodic and saline-sodic were three distinct classes of soil. Agarwal et al. (1979) gave equivalents of the local names (Table-1).

Table-1 : Soil Classes and equivalent local types.

Class	EC mmhos/cm	pH	Local Name
Saline soils	4	8.5	Thur, Uippu, Shora, Solu, Pokkali, Khar and Kari.
Sodic soils	4	8.5	Usar, Rakkar, Bara, Chopan, Karl.
Saline sodic soils	4	variable	Usar, Kallar, Karl, Chopan, Bari, Reh, Choudu, Kshar, and Jougu.

In Uttar Pradesh about 75% population is dependent on agriculture to earn their livelihood. The state comprises 54 districts and 29437 thousand hectares area.

A vast tract 1.2 million hectares, are lying waste due to development of reh and an equally large area affected with soil salinity. The worst affected districts are Aligarh, Mainpuri, Etah, Farrukhabad, Etawah, Kanpur, Fatehpur, Unnao, Hardoi, Lucknow, Rai Bareilly, Azamgarh, Sultanpur and Allahabad (Fig. 9).



#### 4.6. INCIDENCE OF REH IN ALIGARH DISTRICT

Out of 35,000 hectares area in Aligarh district about 7 per cent is Usar and is not being used for agriculture. Another 5 per cent (7,000 hectares) of cultivated land is suffering from salinity and alkalinity (Table-2 ).

Wide-spread Reh (Usar) development is found in Sikandra Rao, Hasayna, Akrabad, Jawan and Chandaus blocks. Dhanipur and Lodha blocks too have wide stretches of such lands. However, Iglas, Gonda, Gangiri and Mursan are affected less and have some unculturable closely spaced sand hills.

Table-2 : Blockwise Distribution of Reh/User lands in Aligarh District (in hectares), 1981-82.

Blocks	Area	Usar or Reh and unculturable lands	Culturable Banjar lands	Current Fallow lands	Other Fallow lands	% of Usar or Reh and unculturable lands of the total area
1. Atrauli	28597	1066	383	506	593	3.72
2. Gangiri	34951	439	1098	1108	906	1.25
3. Bijauli	25308	1605	676	809	855	6.34
4. Iglas	25661	453	202	602	361	1.76
5. Gonda	29575	421	136	997	313	1.42
6. Jawan	31278	4163	763	721	1185	13.30
7. Dhanipur	29394	2050	744	717	1153	6.97
8. Lodha	29110	1621	281	646	768	5.56
9. Khair	32015	1428	926	656	654	4.46
10. Chandaus	326676	2997	1194	440	395	9.17
11. Tappal	37255	890	1786	983	829	2.38
12. Akrabad	26508	3914	812	728	711	14.30
13. Sikandra Rao	26478	4019	603	792	746	15.17
14. Hasayan	29004	4387	1157	864	874	15.12
15. Mursan	22889	153	72	255	127	0.66
16. Sasni	26562	1255	375	350	242	4.72
17. Hathras	23290	677	162	421	352	2.90
<hr/>						
Total area of the blocks	190611	31538	11371	11595	11064	6.42
Total city area	11576	815	300	403	289	7.40
Total area of district	502187	11671	32353	11671	11998	6.44

Source : Office of the Statistics Officer, Economics and Statistics Department, State Planning Organization, U.P., 1983, Statistical Bulletin for Aligarh District, 1981-82, No. 7 (Hindi Edition).

## CHAPTER - V

### SOIL FORMATION AND PROFILE DEVELOPMENT

#### 5.1. INTRODUCTION

The unique characteristic of soil lies in the organisation of constituents and properties into layers that are related to the present day surface and that they change vertically with depth. (Jenny, 1941). This is in direct contrast to the character of the parent material from which the soil is formed.

Soil has been defined as "natural body of mineral and organic constituents, differentiated into horizons, of variable depth which differs from the material below in morphology, physical make-up, chemical properties and biological characteristics" (Joffe, 1949). In soil formation biologic activity figures prominently. During weathering, rock decomposition and soil formation merge indistinguishably into one another. As a rule, they proceed simultaneously, the former paving the way for the later. As such soil formation can be considered an advanced stage of weathering.

Soils are characteristically organised into layers differing in their colour, texture and composition from each other and from the underlying parent material (Fig. 10). The geochemical dispersion of elements largely depend on pH,

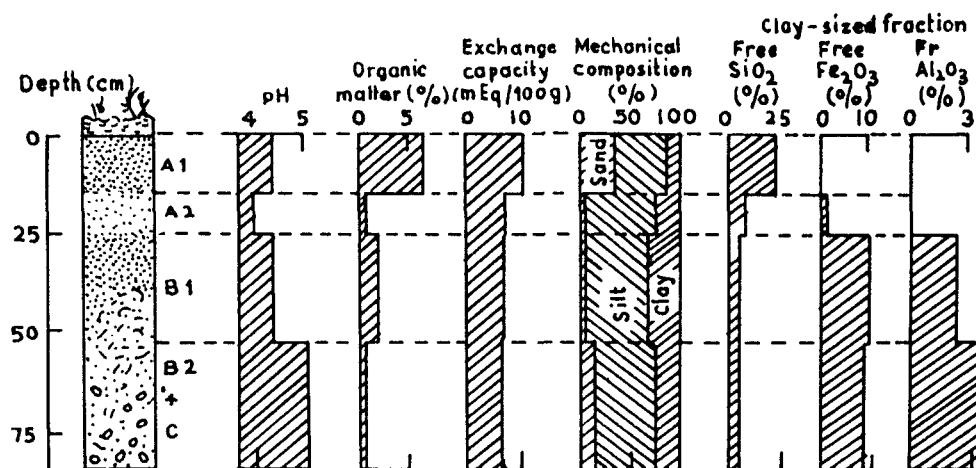


Fig. 10 – Some variations in the physical and chemical properties of the different horizons comprising a soil profile.  
( Hardon, 1936 )

organic matter, clay-mineral type and assemblages, and the amount of Fe-Al-Mn oxides.

The individual layers, referred to as soil horizons, range from a few centimeters to a meter or more in thickness. In general terms, profile development is synonymous with soil formation. It is primarily the result of vertical (upward and downward) movement of material in the form of solution and suspension, accompanied by a complex series of chemical reactions mostly organic. Water is the essential medium in which this transfer and reconstitution takes place.

The soil profiles vary in their make up. Most well-developed profiles, can be divided into four principal horizons designated, from the surface downward, as A, B, C and R. The A and B horizons together constitute the solum or the 'true soil', while C horizon is partly weathered parent material from which the solum has been derived and R horizon is the underlying rock material. Each horizon may further be sub-divided into sub-horizons and designated downward as A<sub>1</sub>, A<sub>2</sub> ..... etc. A horizon of nearly pure organic matter (O or A<sub>o</sub>) may lie above the A horizon. A hypothetical soil profile is shown diagrammatically (Fig. 11).

The A horizon is characterised by partial leaching known as eluviation (Latin "to wash out"). Some of the constituents are removed as true solutions through downward moving water; others are removed as dispersed colloidal particles. Humus is almost always present in the A horizon.

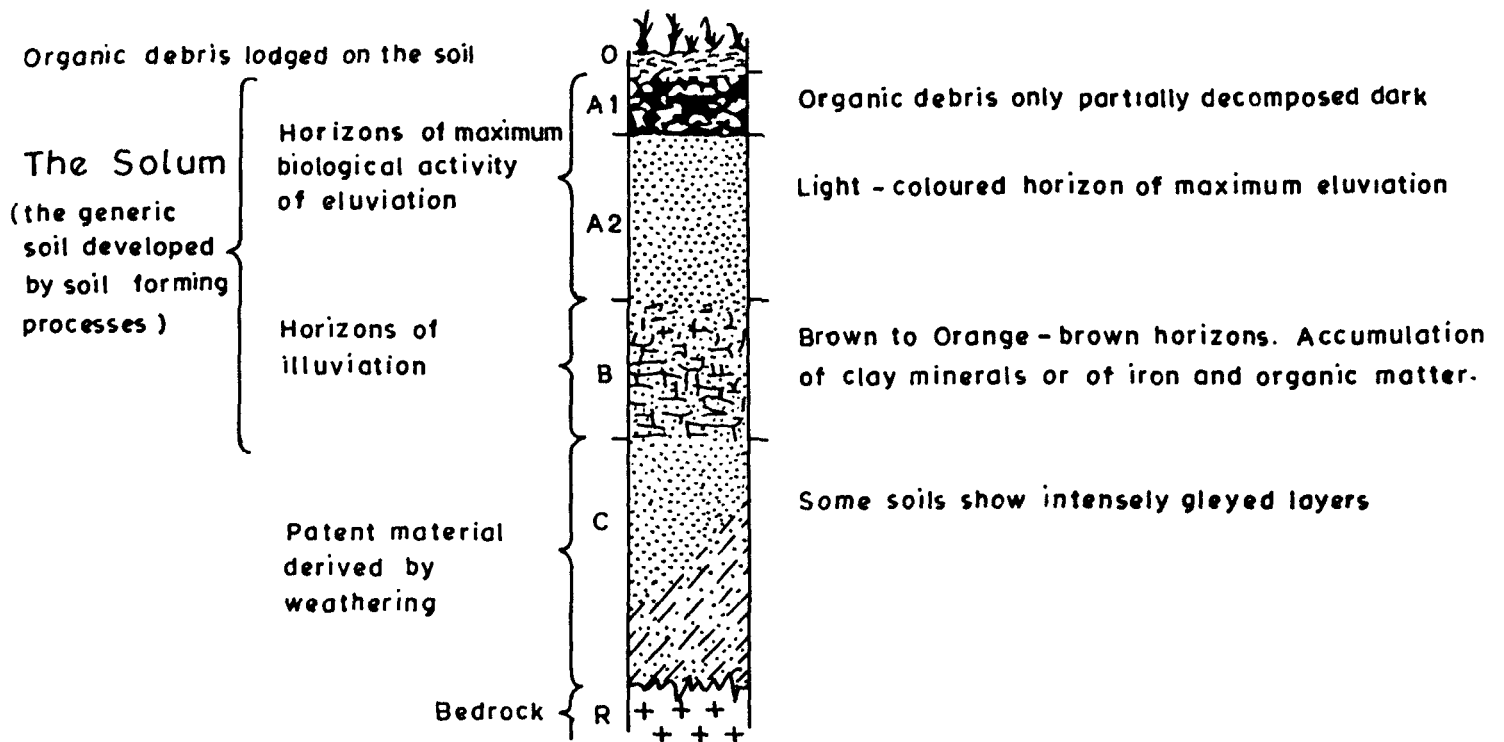


Fig. 11 Hypothetical soil profile showing the principal horizons

Various complexing agents, organic acids and  $\text{CO}_2$  which promote leaching in the A horizon, are generated by bacterial action and decay of humus. Carbonic acid and organic acids furnish  $\text{H}^+$  that contributes to decomposition of minerals and dislodges the bases (Ca, Na, Mg, K) from the exchange sites of clay minerals, clay size oxides and organic materials. The bases move downward as dissolved ions, Fe and Al move as colloidal particles of clay minerals and the oxides as complexes with organic groups or, in most acid soils, as free ions or ions complexed with hydroxyl. Silica is generally dissolved forming silicic acid ( $\text{H}_4\text{SiO}_4$ ) or moved as colloidal silica. Since the resistant primary minerals and rock material are left behind in the upper soil, the B horizon gets enriched in clays and Al-oxides. The red or yellow brown colour in those profiles are due to enrichment in Fe-oxides on account of illuviation. In some profiles, the B horizon may also gain material by ascending soluble matter from the underlying horizons. Illuviation takes place in less acid environment during the downward percolation of ground water. It also depends on the dissolved solid matter. These changes flocculate the colloidal material and precipitate oxides.

The C horizon, parent to A and B horizons, is the weathered horizon which may be in situ or transported. Soil of a past pedological cycle. As a rule, inorganic decomposition extends for deeper than the soil horizons. Thus the C horizon

can be subdivided into various zones of weathering with intensity decreasing with depth. The organic matter and clay content is minimum in the C horizon, due to which it is lighter in colour than the B horizon. The relict rock structures and textures are better preserved in this horizon than in the overlying ones. Metals from this horizon is taken up by deep-rooted plants and transferred to the surface as organic debris. Their subsequent fate is determined by the stability of compounds formed by them in the A horizon. Some of the metals get transferred to B horizon along with the hydrous oxides of Fe and Mn or the clays.

## 5.2. FACTORS AFFECTING SOIL FORMATION

The soil profiles often differ widely from the ideal one due to the following variable factors :-

1. Climate (C)
2. Organisms/Biologic Activity (O)
3. Topography (Y)
4. Parent material (P)
5. Time (t)

The soil forming process is extremely slow and, therefore, escapes observation. Various soil geneticists, from Dokchaev to present, have mentioned five general factors, mentioned above, in the soil formation. The degree of influence exerted



by each of these factors individually and in various combinations make an interesting study in the genesis of soils and their profiles.

Jenny (1941) proposed the following equations to express various relationships :-

$$S = f_{cl} (\text{climate})_o, r, p, t \dots\dots$$

$$S = f_o (\text{organisms})_{cl}, r, p, t \dots\dots$$

$$S = f_r (\text{topography})_{cl}, o, p, t \dots\dots$$

$$S = f_p (\text{parent material})_{cl}, o, r, t \dots\dots$$

$$S = f_t (\text{time})_{cl}, o, r, p \dots\dots$$

Where S = any soil property, e.g. organic matter, clay content  
or free iron oxide content

f = function of or dependent upon

Cl = Climate

O = Organisms

r = relief (topography)

P = Parent material

t = Time (age)

The above equations state that the property (S) of a group of soils is affected by variation in factors.

Later on, he (1961) modified the above equation to bring out the principle that, in the development of a given soil property, the factors outside the parenthesis are not really constant, as implied by the equation, but are ineffective,

that is, the partial derivative of the property with respect to these factors is nearly zero. Therefore, Jenny (1941) proposed that in writing these equations all the factors should be placed within the parenthesis, the principal factor be listed first and printed in a distinguishing type such as to indicate its dominance, thus :-

$S = f(Cl, o, r, p, t \dots\dots)$  climofunction

$S = f(O, Cl, r, p, t \dots\dots)$  biofunction

$S = f(r, Cl, O, p, t \dots\dots)$  topofunction

$S = f(t, Cl, O, r, p \dots\dots)$  chronofunction

Thus any soil properly is a function of the collective effects of all the soil forming factors.

#### 5.2.1. Passive and Active Factors

Joffe (1949) divided soil forming factors into 'Passive' and 'Active'. Passive factors are the source of the soil forming mass and conditions affecting it, namely, parent material, relief and time. Active factors are those which represent agents that supply energy that act upon the mass during the soil formation and comprise climate and biosphere (vegetation, organisms and man).

The inter-relationships among these factors are complex and the effects of any one factors cannot be isolated and identified with certainty. It is convenient, however, to

discuss the factors of soil formation individually in order to understand their roles in soil formation. However, the formation of soil may be governed by interactive role of the two.

### 3.3.1. Climate

It determines the nature of weathering and the rates of chemical and physical processes.

#### Rainfall

In arid regions, rain water is either held by the soil particles or moves upward through evaporation and transpiration by plants. In humid regions, however, a large part of the rain water percolates through the profile carrying with it the dissolved matter. Thus, leaching is involved. The soils of arid regions, thus, are richer in soluble constituents and plant food in comparison to those of humid regions. Consequently, the soils become alkaline in arid climate and acidic in the humid ones.

The saline and alkaline soils fall into two groups the solon-chak and chernozems. The solonchaks dissolve humus in alkali carbonates and carry it down to a lower layer, which, when dried, contracts forming columnar structure. In the semi-arid climate, there is a considerable vegetative growth during the wet season without appreciable decay of the organic matter

during the dry period forming the black soils or chernozems. Under the cool humid conditions, the bases are leached, organic matter is partially decomposed and effect leaching of the sesquioxides. The sesquioxides may be distributed throughout the weathered material giving rise to Brown Earths. Alternatively, they may be deposited at a lower level leaving a bleached layer above giving rise podsol soils.

Therefore, it is the amount of available percolating water that controls the qualitative and quantitative distribution of the substances through the profile and not the total annual rainfall in a region.

In general, with increasing moisture, the contents of nitrogen, carbon, clay, aggregation, saturation capacity, and exchangeable hydrogen tend to increase in the soil. At the same time, exchangeable bases and pH decrease. The depth of calcium carbonate horizon in pedocal (lime accumulating) soils increase with increasing moisture.

#### Temperature

Temperature controls the rate of reaction in soils. It is estimated that for every  $10^{\circ}\text{C}$  rise in temperature, the rate of chemical reaction doubles. Biochemical changes too are most sensitive to temperature variation. With excess moisture, the process of leaching is hindered and water soluble salts move up through capillary action (Murshal, 1959). The precipitation

of calcium, magnesium and other soluble salts as carbonates or sulphates is indicative of relatively dry climates during pedogenesis. Low temperature, on the other hand, induces leaching temperature colloidal materials may, likewise, rise. The capillary rise of colloidal material followed by coagulation gives rise to a concretionary horizon near the upper level. Most iron oxides and colloidal silica commonly accumulate in this manner. Incomplete leaching of soils in arid to semi-arid areas adds to alkalinity. In tropical areas, some thoroughly leached soils may have developed under conditions of much higher rainfall. The rate of weathering in such areas is three times faster than in temperate regions, and nine times faster than in the arctic (Jenny, 1941).

### 5.2.3. Organisms (Biologic Activity)

Vegetation and micro-organisms help decompose plant debris. Generally, dry climate inhibits soil forming activity and warm climate increases it. As a result there is no accumulation of humus, instead organic acids are generated during the decay of the litter. Thus, maximum accumulation of humus is to be expected in cool climates only.

Deep rooted plants speed up leaching by indirect transference of elements to top soils.

Agricultural activities, such as, irrigation and reclamation affect profile development. Cultivation depletes the

organic matter and plant nutrients, manuring adds to organic content and fertilizers alter pH and fertility status of the top soil. Excessive irrigation may raise water table, deposit fresh sediments and, sometimes, increase salinity and alkalinity.

#### 5.2.4. Topography

Topography or relief affects the ground water levels, drainage system and erosion. In the regions of moderate to high rainfall the A and B horizons are strongly differentiated. Such profiles develop most readily on the interfluvies in undulating country. In the low-lying areas, the terrain may be saturated with water, almost to the surface which may form a very different profile. An organic rich surface layer will develop over a pallid or mottled subsoil, result of reducing environment and minimal leaching.

If water stands at the surface, peat may form. In semi-arid regions a temporary water table may exist along side rivers in the wet season and induce the formation of saline profiles behind Levees where the water table lies near the surface (Fig. 12).

The changes from one drainage condition to another are usually transitional and give rise to a related sequence of profile types which constitutes a soil catena. There is a close relationship between the slope angle, drainage and erosion. On the slopes of 25 to 40 per cent, A and C horizons

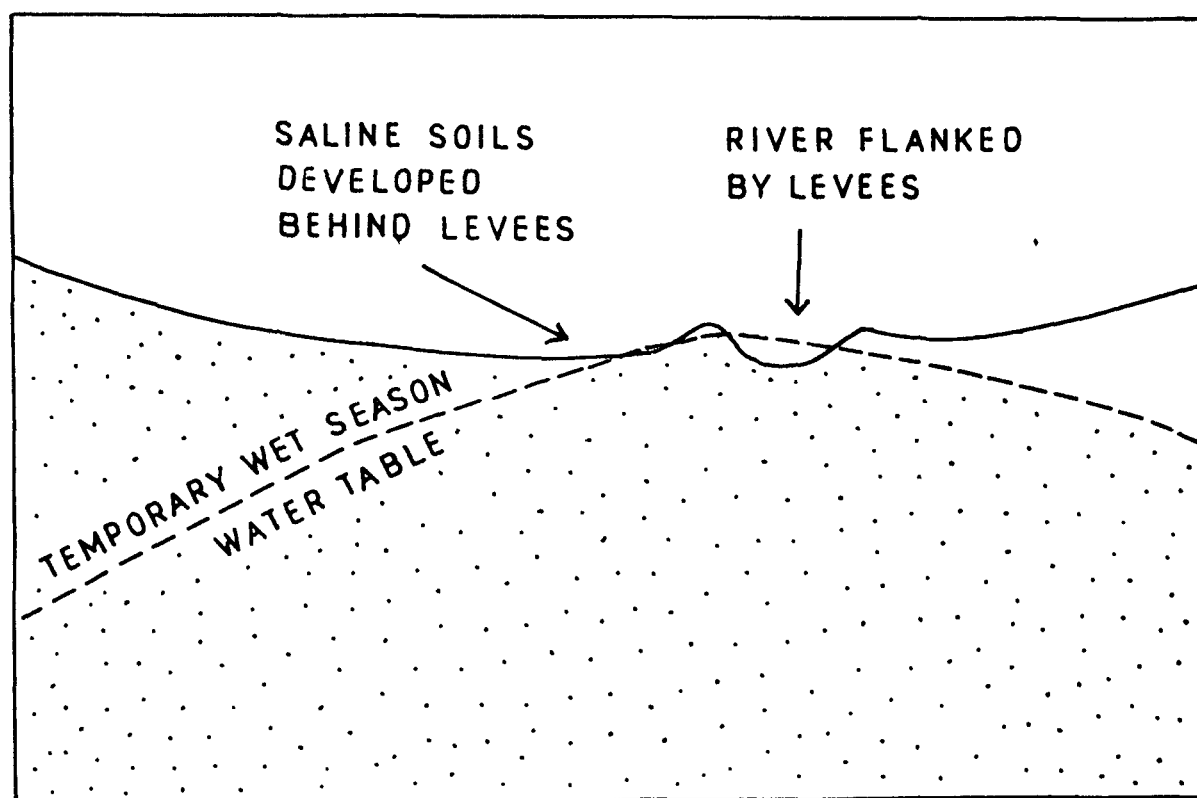


FIG.12 DIAGRAMATIC SECTION SHOWING INFLUENCE OF  
GROUND WATER IN THE DEVELOPMENT OF SALINE  
SOILS

develop normally. This is because of higher rate of erosion resulting in a shallow A<sub>0</sub> horizon. With even greater rate of erosion truncated profiles may develop in the upper slopes, accompanied by burial of the original profile at lower topographic levels.

On the slopes and uplands, good drainage produces well aerated, oxidized soils with bright coloured B horizons and low organic content. In the low lands and depressional areas, poor drainage will produce dark grey B horizon and A horizon rich in organic content.

This can be explained due to low oxidation caused by water logging.

#### 5.2.5. Parent Material

The contribution of the parent material is an important factor in controlling the nature of the resultant soil. Geologic features may, at times, be reflected in the residual soils in regions of relatively uniform climate with other factors constant. The composition, texture and structure of parent material influences the rate of weathering.

The decomposed/disintegrated parent material of soils can be grouped under four classes :-

1. In situ derived from the underlying hard rocks (igneous, metamorphic).



2. In situ derived from the underlying soft or unconsolidated rocks (sedimentary).
3. Transported and prior to pedogenic activity.
4. Organic.

Tables-3, 4, 5 and 6 summarise the combinations of parent material to the soils.

Evenly highly weathered and diverse types of residual soils often make it possible to detect variations in the underlying rocks by determining their mineral assemblage and the mechanical composition. Clay formation is related to the concentration of bases in the original material. For instance illite, forms by mild weathering of potash micas and montmorillonite from minerals high in calcium and magnesium. Moreover, the type and concentration of trace elements in the soil may also provide clue about their provenance.

#### 5.2.6. Time

The accumulation of parent material by weathering takes longer than its differentiation into soil horizons. Given a moderate humidity and free drainage, faint A horizons may develop after some decades. The development of a distinct B horizon normally requires a much greater length of time, often measurable in centuries or even tens of thousands of years (Fig. 13).

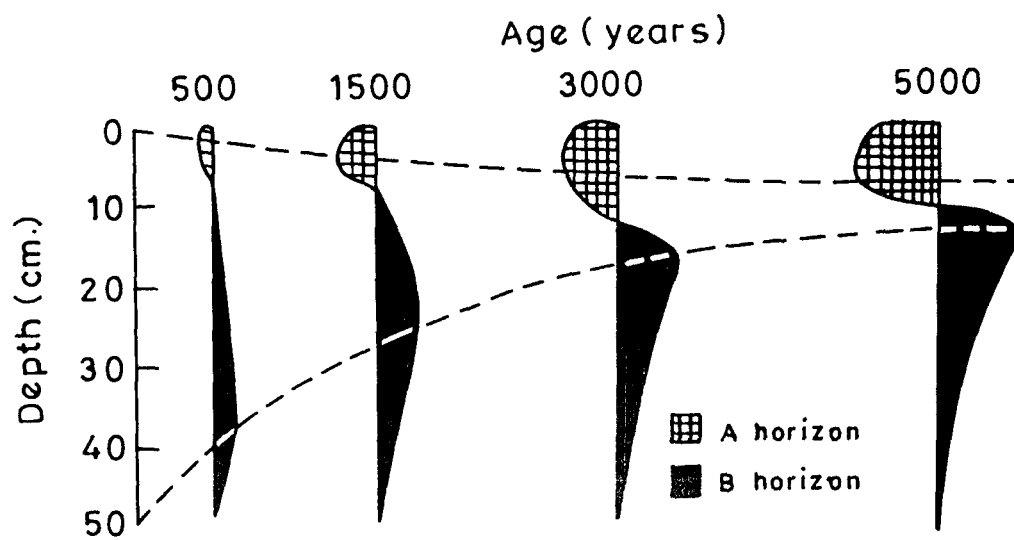


Fig. 13 — Formation of A and B horizons of a podzol profile as a function of age.

(After Jenny, 1941.)

Tables-3 to 6

Contribution of selected rocks and minerals to  
the soil

Table-3 : Igneous Rocks

Texture	Colour		
	Dark	Intermediate	Light
Coarse	Gabbro	Diorite	Granite
Intermediate	Basalt	Andesite	Rhyolite
Fine			Obsidian
Rock	Average Minerals Components		
Granite and rhyolite	50% feldspar		
	30% quartz		
	20% iron and magnesian minerals		
Basalts and Gabbro	50% feldspars		
	50% iron and magnesian minerals		
Diorite and andesite	75% feldspars		
	25% iron and magnesian minerals		
Obsidian	60% feldspar		
	30% quartz		
	10% iron and magnesian minerals		

Table-4 : Sedimentary Rocks

Rock	Minerals present	Rock characteristics	Soil formed
Limestone	Dolomite or calcite	Variable in colour from white to grey to light red and yellow	Basic soils high in calcium and magnesium.
Sandstone	Mainly quartz	Variable, white to red to brown	Acid soils which will leach quite easily and be low in nutrients
Shale	Clay minerals, some quartz and organic matter	Layers structure variable colour depending on minerals present	Variable depending on amounts of quartz and ferro-magnesian minerals present.
Conglomerate	Variable	Cemented gravel and rock fragments larger than 2 to 4 mm.	Variable but usually coarse and contain much gravel.

Table-5 : Metamorphic Rocks

Metamorphic Rocks	Original Rocks
Quartzite	Sandstone
Slate	Shale
Marble	Limestone
Schist	Basalt
Gneiss	Granite

Table-6 : Minerals

Mineral Group and species	Contribution to the soil
<b>Feldspar :</b>	
1. Orthoclase	Potassium, forms clay
2. Albite	Sodium, forms clay
3. Plagioclase	Sodium, calcium, forms clay
<b>Amphiboles :</b>	
1. Hornblende	Calcium, magnesium, sodium some iron.
<b>Micas :</b>	
1. Muscovite	Potassium, forms clay
2. Biotite	Potassium, forms clay
<b>Silica :</b>	
1. Quartz	All are resistant to weathering and are the main components of the soil.
2. Cristobalite	
3. Chalcedony	
<b>Iron Oxides :</b>	
1. Hematite	All contributes iron to the soil and are responsible for the red and yellow colours in the B horizons of well drained soils.
2. Limonite	
3. Goethite	
4. Magnetite	
<b>Carbonates :</b>	
1. Calcite	Calcium common limestone
2. Dolomite	Calcium, magnesium
<b>Other Minerals :</b>	
1. Gibbsite	Aluminium
2. Apatite	Phosphorus
3. Tourmaline	Boron
4. Zircon	Resistant to weathering, used to index soil age.
5. Pyrite	Iron and sulphur
6. Gypsum	Calcium, sulphur

continued.....

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Mineral Group and species	Contribution to the soil
------------------------------	--------------------------

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Clay Minerals :

- |                    |                                       |
|--------------------|---------------------------------------|
| 1. Kaolinite       | Found accumulated in most soils.      |
| 2. Montmorillonite | Give rise to the most of the chemical |
| 3. Vermiculite     | and physical properties observed in   |
| 4. Illite          | soils.                                |
-

Thus, soils can be classified as Juvenile or mature according to their state of development. Where erosion is dominant, soil will necessarily remain in a juvenile condition irrespective of time. If the time factor is adequate. If the rate of erosion is not faster than the date of soil formation, a mature profile will eventually result.

### 5.3. CLASSIFICATION OF SOILS

There is no uniform nomenclature for soils because there is great variation in conditions from region to region. Moreover, different bases were used in various classifications. A genetic soil profile concept (Dokuchaiev in Glazovskaya, 1966) was developed during the later half of 19th century. Later a geographic-genetic or genetic factor was introduced (Sibrtseve, 1896). Hilgard (1906) accepted Dokuchaiev's classification and considered soils as independent natural bodies.

The older system of classification such as an early U.S. system by Throp and Baldwin (1938), though largely genetic, were based on the inferred genesis of soils controlled by the climate, drainage, relief of the area, parent material, etc. More recently classifications of soils tend to be rather descriptive, with emphasis on certain chemical and physical features that can be unambiguously identified. They also reflect their genesis as well as their relationship to the growth of crops. A most widely used classification, in soil



taxonomy of the U.S. Department of Agriculture (soil survey staff 1975), incorporates a new set of terms and soil types based on quantitative measurement of the chemical and physical parameters (Table-7 to 9).

Many systems of soil classification presently in use incorporate many of the terms and concepts of the U. S. Soil Taxonomy System, as for example, the classification used by the Food and Agriculture Organisation (F.A.O.) of the U.N. in preparing the soil map of the world (1974).

The F.A.O. system of soil classification has now been widely accepted by a large number of scientists the world over.

Table-7 : Diagnostic Soil Horizons (U.S.D.A., 1975; Young, 1976; Dregne, 1976).

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#### A. Horizons Formed at the Surface (A-horizon)

1. Histic A horizon : peaty or mucky, organic matter  $> 20\%$  usually water saturated. Diagnostic of histosols.
2. Mollic A horizon : A granular dark horizon  $> 18$  cm thick with organic matter  $> 1\%$  and base saturation  $> 50\%$ , Ca is main exchangeable cation. Typical of grasslands, diagnostic of mollisols.
3. Umbric A horizon : Similar to a mollic horizon but with base saturation  $< 50\%$  typical of forested areas.

4. Ochric A horizon : A relatively pale or thin surface horizon not qualifying as mollic, umbric, or histic, organic content  $< 1\%$ , typical of arid regions and some forested regions.
5. Horizons formed beneath the surface (B-horizons)
  1. Argillic B horizon : Accumulation of illuvial clay, as indicated by clay coatings or markedly higher clay content than overlying horizons. Present in alfisols and ultisols.
  2. Cambic B horizon : Texturally distinguishable from A horizon but lacking illuvial clay, Fe-Al-oxides, organic matter or alkali enrichment may be present in inceptisols and mollisols.
  3. Natric B horizon : Like an argillic B horizon, but alkali-enriched, exchangeable Na  $> 15\%$  of total exchange capacity, columnar structure. Present in some aridosols and mollisols.
  4. Oxic B horizon : Highly weathered, composed of kaolinite, Fe-Al-oxides very low cation exchange capacity (  $< 15 \text{ m}/100 \text{ gm clay}$ ), no clay coatings diagnostic of oxisols.
  5. Spodic B horizon : Accumulation of organic matter and Al-oxides with or without Fe-oxides and without clay coatings, usually beneath albic horizon. Diagnostic of spodosols.

### C. Other Horizons and Properties

1. Albic horizon : Subsurface horizon from which clay and Fe-oxides have been leached, leaving a strongly bleached horizon, usually beneath an organic-rich A horizon and above a spodic B horizon (A<sub>2</sub> horizon of horzols).
  2. Calcic horizon : Accumulation of appreciable carbonate.
  3. Gypsic horizon : Accumulation of gypsum.
  4. Salic horizon : Accumulation of salts more soluble than gypsum.
  5. Gley horizon : A blue-grey subsurface water logged horizon, reducing, and usually mottled with spots of brown to yellow.
  6. Ferric properties : With red mottles and concretions, and low cation-exchange capacity.
  7. Base Saturation : The fraction of exchange sites on clays or other colloidal particles that is occupied by Ca, Mg, Na and K, the remaining sites are occupied mainly by H and Al. Base saturation is measure of the degree of weathering and leaching. It tends to decrease with increased weathering and leaching.
  8. Aridic Moisture Regime : Profile not moist throughout for more than two consecutive months, nor moist in some part for more than three.
-

Table-8 : Soil Orders (U.S.D.A., 1975).

Soil order and suffix to form name of sub- order	Latin or other root	Description
Entisol(-ent)	Recent	Soils lack significant profile development, consist of little modified parent material.
Inceptisol(-ept)	L. inceptum beginning	Soils with weakly developed horizons of alteration of parent material, but not accumulated.
Spodosol(-od)	L. spodos wood ash	Soils with a spodic B horizon.
Alfisol(-alf)	Al-Fe	Soils with an argillic or natric B horizon and a base saturation > 35% moist part of the time; lack calcic, gypsic, or mollic horizons.
Ultisol(-ult)	L. ultimus last	Soils with an argillic B horizon and base saturation < 35%; warm moist of the time.
Oxisol(-ox)	Oxide	Soils with an oxic B horizon.
Aridosol(-id)	L. aridus dry	Soils with an aridic moisture regime, an ochric A horizon and high base saturation, may have calcic, gypsic, argillic or natric B horizons.
Mollisol(-oll)	L. mollis soft	Soils with a mollic A horizon and high base saturation in B horizon.
Vertisol(-ert)	L. verto change	Soils with a high content of swelling clay, forming wide cracks when dry into which surface soil falls or is washed.
Histosol(-ist)	L. histos tissue	Soils with a histic (peaty) A horizon (organic soils).

Table-9 : Approximate correlation of Soil Orders between various systems (Aubert and Tevernier, 1972; Young, 1976).

	U.S.D.A. (1975)	Old System or sub-division	F.A.O. (1974)
1	2	3	4
<u>Zonal Soils</u> :			
1. Soils of cold climate	Inceptisols mollisols (cryo-or ag-prefix)	Tundra(gleyic) soils Arctic brown soils	Gleysols
2. Podzolic and related soils of temperate and tropical forested regions	Spodosols  Alfisols     Ultisols  Oxisols	Podzol Brown Podzolic soils  Gray-brown Podzolic soils Gray Podzolic soils Non-calcic brown soils Degraded chernozems  Red-yellow Podzolic soils	Podzols  Luvisols    Acrisols
3. Soils of semi-arid, sub-humid and humid grasslands	Mollisols     Vertisols	Degraded chernozems Prairie soils Reddish Prairie soils  Chernozem  Chestnut soils Reddish chestnut soils Brown soils (in part)  Grumusols	Phaeozem    Chernozem  Kastanozem  Vertisols

continued.....

1	2	3	4
4. Light coloured soils of arid regions	Aridosols	Brown soils(in part) Reddish brown soils Sierozem soils  Desert soils Red desert soils	Xerosols    Yermosols
<u>Intrazonal Soils :</u>			
1. Hydromorphic soils of marshes, swamps, flats and seepages	Aqu-Prefix	Humic-gleysoils  Alpine meadows soils Low humic-gley soils Planosols Ground water Podzols Ground water Latasols	Gleysoils
	Histosols	Bog soils Half-bog soils	Histosols
2. Halmorphic (saline and alkali) soils of imperfectly drained arid regions	Sal, natr-Prefixes	Solonchak Solonetz	Solonchak Solonetz
3. Calcimorphic soils	Rend-Prefix	Brown forest soils Rendzina	Rendzina
<u>Azonal Soils :</u>			
1. Soils on little weathered parent material	Entisols	Lithosols Regosols Alluvium	Lithosols Regosols Fluviosols
2. Soils with only incipient horizons	Inceptisols		Andesols Cambisols

#### 5.4. THE SOIL TAXONOMY SYSTEM

The diagnostic horizons are (Table-7) the key to separation and classification of the orders (Table-8). The soils are divided broadly into ten orders on the basis of the types of 'diagnostic' horizons present. These horizons are also of critical importance in controlling the dispersion of trace metals in the soils. For example, Oxisols are highly leached soils, and alfisols are leached less than ultisols. Equivalents of these in the old system are mentioned in Table-9.

The orders are further subdivided into suborders on the basis of climate, drainage or other distinctive features or properties. The suborders are named using a prefix denoting 'formative element' (Table-10) and a suffix denoting the order. For example, an aquod is a water-saturated (aqua-) spodosol (-od). In the old system this was designated as ground water podzol. In this way about 50 suborders were recognized. Further detailed subdivision are successively into great groups, subgroups, families, series, and phases. The Great Groups are formed by adding a Prefix to denote diagnostic horizons or variants of horizons. The names of subgroups are formed by an adjective preceeding the name of the Great Group indicating its gradational position in relation to the neighbouring Great Groups. Family names add more adjectives to indicate properties important to plant growth. For example, a family name for a

given soil might be fine-loamy mixed aquic hapludalf (a wet soil with a poorly leached clay-rich B horizon, formed in a humid region with minimal development of diagnostic horizons).

In general, all these soil types can be placed in three categories, viz., azonal, zonal and intra zonal. Azonal soil is characterised, mainly, by the parent material and incipient horizons with immature soils. The immature soils are recent alluvium, volcanic ash, wind-blown sands and shallow bed-rocks. In the Soil Taxonomy system are entisols and inceptisols and include the lithosols, regosols, and alluvial soils. The zonal soils are characterised by mature soil profile. The podzol, chernozems, latosols, and desert soils of the old classification schemes are the zonal soils of the Soil Taxonomy system, and, in part, equivalent to spodosols, mollisols, oxisols and aridisols, respectively. In the intrazonal soils, local conditions, such as drainage, plays a dominant role, so that soils in different climatic regions resemble each other more closely than the zonal soils of the region in which they occur. For example, in humid regions, soils in areas with poor drainage develop a water-logged reducing zone beneath the surface. Such reducing sub-surface zones are known as gley horizons and are characterized by a pallid blue-grey mottled or streaked appearance, with Fe predominantly in the state. These soils are denoted by gley, gleyic ground water or similar terms in the old classification and by the prefix aqua- in the Soil



Taxonomy. Similarly, in arid regions, low or poorly drained areas develop salt-rich or saline soils denoted as solonchak or solonetz in the old system and by prefixes natr- and sal- in the Soil Taxonomy.

Table-10 : Prefixes used in naming sub-orders according to formative elements (U.S.D.A., 1975).

---

And-	Soils from vitreous volcanic parent material
Aqu-	Soils that are wet for long period
Arg-	Soils with a horizon of clay accumulation
Bor-	Soils of cool climates
Fibr-	Soils with minimal decomposition
Hum-	Soils with organic matter
Ochr-	Soils with little organic matter
Orth-	Soils typical of their order
Psamm-	Sandy soils
Sapr-	Soils of humid climates
Umbr-	Soil with dark surface layer reflecting much organic matter
Ust-	Soils of dry climate with summer rains
Xer-	Soils of dry climates with winter rains

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## 5.5. CLASSIFICATION OF SALT AFFECTED SOILS

Throp and Smith (1949) proposed a genetic classification according to which saline and alkali soils (Solanchak, Solonetz and Solochs) were placed in a halomorphic group without distinctions. Later on three distinctive types of soils, viz., saline, alkali and saline-alkali were recognised in this group (Richards et al., 1954). The group was investigated by a host of workers and evolved into what is now called as modern classification of soils.

### 5.5.1. Modern Approaches in the Classification of Saline Alkali Soils

#### (a) The Russian Approach

The Solonetz, semi-desert and meadow soils were differentiated into nine major types on the basis of genetic profile concept (Pak, 1971). The differentiation of Solonchak was made on the basis of the soluble salt content. Further subgrouping into classes involved anionic-quotients like chloride, nitrate, sulphate and carbonate, etc. (Kovda, 1961). The classes are as follows :-

- i. Soda Solonchak
- ii. Sulphate Solonchak
- iii. Chloride Solonchak
- iv. Nitrate Solonchak

The criterion of ionic specificity of the salt content,

according to their physical and physiological roles, resulted in the formulation of non-uniform limits of salt content. The different ionic types, however, fell within the same salinity class (Driessen, 1970).

Subsequently, a typical Solonetz profile comprising following horizons was described by Kovda (1972) :-

Eluvial A — alluvial, prismatic, blocky B<sub>1</sub> —  
Carbonate B<sub>2</sub> — Salt.

#### (b) The American Approach

The American approach differs from that of the Russian in the following respects :-

- i. Absence of specifications about the nature of electrolytes, and
- ii. Class limits of salt content.

The comprehensive U.S.D.A. classification (1960, 1970) reflects soil properties in the nomenclature. The soil characteristics selected are those which are measurable. However, it drew mild criticism for being extra profile (Gerasimov, 1969) or inconsistent (Nebster, 1968).

According to this system, soils were grouped into ten orders based on (i) surface diagnostic horizons, viz., ochric, mollic, umbric, histic, anthropic and plaggen; (ii) subsurface diagnostic horizons, viz., argillic, natric, agric, cambic,

spodic and oxic and (iii) additional horizons, viz., calcic, gypsic and salic and two hard pans, duripan and fragipan. The saline-alkali soils find place in the salorthids, natrargids, halaquepts, natrustalFs, natraqualfs, natraquolls or natrastolls great groups within the system.

(c) The F.A.O. Approach

The F.A.O. approach is a combination of a few selected genetic elements in a highly formalised manner. Like American system, this has :-

- i. Four types of A horizons viz., melanic (humus with base saturation  $< 50$  per cent), Sombric (saturation  $> 50$  per cent), histic (coarse humus with 20 to 30 per cent organic material), and
- ii. Five types of B horizons viz., argillic, natric, cambic, spodic and
- iii. Five additional types of horizons, viz., calcic, gypsic, salic, plinthic and gleyic.

The natric and salic horizons, as in the American Soil Taxonomy system, describe the conditions of alkalinity or salinity. But unlike the U.S. system it provides for a separate unit for Solonchak while other soils, not so distinctly saline or alkaline, find place under the broad soil unit of 'Halosols'

with sub-units of ochric solonetz, humic solonetz, gleyic solonetz, ochric solonchaks and humic solonchaks.

Some of the U.S. solonetz soils closely resemble the solonetz soils described by Kovda (1973) from Russia, specially, in the presence of soluble salts below the natric horizon. However, the F.A.O. System stipulates more than 6 per cent saturation of sodic phase with negligible exchangeable sodium in some horizon within 100 cm of the surface. The natric phase, unlike solonetz has B horizons with a high exchangeable sodium saturation. The solonchaks, according to the F.A.O. system, have at least 2 per cent easily soluble salts in the upper most (30 cm) soil horizons.

#### (d) The Hungarian Approach

De Sigmond (1927) classified alkali soils into three main types as follows :-

- i. Soils rich into alkali and  $\text{CaCO}_3$
- ii. Soils having less alkali but considerable amount of  $\text{CaCO}_3$
- iii. Soils rich in alkali but free of  $\text{CaCO}_3$ .

According to Abraham and Boeskai (1971) Solonetz are of the following types :-

- i. Solonchak Solonetz
- ii. meadow Solonetz

- iii. Meadow Solonetz turning into steppe
- iv. Solonized meadow
- v. Solod.

The meadow solonetz is the abundant type. The central character of these soils is similar to those of the Russian solonetz. Their chemical characteristics (Darab, 1971), show a degree of overlap within the meadow solonetz, meadow solonetz turning into steppe and solonetzic meadow soils.

Apart from these, a number of other systems of soil classification were proposed to cater the specific needs.

#### 5.5.2. Classification of Saline Alkaline Soils in India

There is no generally acceptable classification of saline-alkaline soils in India although, typical saline, alkali or saline-alkali soils abound in varied geoclimatic regions.

Characterisation of salt affected soils has been attempted by several workers (Kanwar and Sehgal, 1962; Raychaudhary et al., 1962; Kanwar and Bhumbla, 1969; Abrol and Bhumbla, 1971; Bhargava, et al., 1972; Bhumbla et al., 1973; Sehgal et al., 1975; Manchanda and Khanna, 1981; and Manchanda et al., 1983). The saline-alkali soils have been grouped into four categories on the basis of geographical distribution.

Raychaudhary (1973) described three unique soil conditions viz., saline, highly alkaline-saline and slightly alkaline-

saline. Six different kinds of problem soils identified were alkali, saline, potentially saline, coastal saline, deltaic saline and saline sulphates.

### 5.5.3. Classification of Salt affected Soils of Indo-Gangetic Plain

The alkali soils in the Indo-Gangetic plain constitute nearly 2.4 million hectares area (Bhargava et al., 1975). Most of these are analogous to soda-solonchaks or black alkali soils of the Russian system. They are characterised by high sodium carbonate and bicarbonate, high pH value (average 10.7) and high sodium saturation of the exchange complex, often exceeding 80 to 90 per cent. Possibly a shallow non-saline ground water table existed during some part of the year (Abrol et al., 1971; Bhargava et al., 1972; Bhumbra et al., 1973; Sehgal, 1975). To account for the salinity which is low for a salic horizon but high enough for agricultural purpose. Sehgal et al., (1975) and Bhargava et al. (1975) redefined the natric horizon and proposed a salic subgroup.

Alkali soils are light coloured (generally yellow), poorly aggregated, up to 10 cm or more in thickness and infertile. They occur in subtropical and semi-arid regions with average rainfall of 720 mm and maximum and minimum temperature of 31.7° and 18°C, respectively (Bhumbra et al., 1973).

Of the six epipedons defined in the 'Soil Taxonomy', none describes the surface alkalinity conditions but characterised as ochric irrespective of their paragenesis. The system also does not distinguish between the surface and subsurface, alkalinity. The genetic significance of illuvial horizons play key role in the landuse or meliorative planning. It is therefore, essential to define and specify natric epipedon.

#### Natric Epipedon

The natric epipedon is very light coloured (yellowish) with high chromas and values that are required to qualify for mollic, umbric, anthrotic or histic epipedons. They are at least 10 cm or more in thickness with texture finer than those of loamy fine sand. A few mm thick salt crust (mostly carbonate and bicarbonate of sodium) occurs for some period during the summer solstice. The surface turns loose and fluffy under dry and desiccating conditions. The colloids get deflocculated when irrigated or inundated but seldom gets hard and massive. This includes eluvial horizons at the surface extending to the argillic natric or cambic horizons.

Adhering to the definitions of the natric epipedon, three types can be distinguished :-

- i. Epinatric natrustalfs
- ii. Epinatric haplustalfs
- iii. Natrustalfs.



The epinatric natrustalfts, the most difficult one, for soil melioration, has the entire alkaline profile. The next in order is haplustalfts which require surface soil reclamation only as their substratum is free of alkali hazards. The natrustalfts present potential problem for the upper part of the soil if proper care is not taken.

#### 5.5.4. Problems in the classification of Saline Alkali Entisols and Vestisols

The subgroups, salic and natric, are proposed for the soils with high salinity and alkalinity. The salic subgroup has average minimum neutral salts of less than 1% in any layer within the upper 1 meter or above the ground water table, whichever is shallower. Also the product of per cent salt and thickness does not exceed 30 within 75 cm from the surface or above the water table. The aquents and fluvents; the two salic types, fall under these categories. The coastal soils are, generally, too stratified, fine to loamy and highly saline. The shallow saline water table always remains within 1 meter of the surface. The surface horizons contain water soluble salts, mostly chloride and sulphates, with a salic horizon.

In the natric subgroup of entisols, the texture is finer than loamy fine-sand but not finer than coarse loamy. The

sodium content exceeds 15 per cent within the upper 50 cm. The hydraulic conductivity remains low to very low.

The salic and natric sub-groups can be

- i. Salinatrfluvaquents, containing excess water-soluble salts somewhat less for salic horizon, and
- ii. Natric salfluvaquents, with fine loamy texture and ESP values less than 15.

Sometimes vertisols are also affected by salinity/alkalinity. The deep to medium black soils (Govinda Rajan, 1970) and 'regurs' (Abrol and Bhumbla, 1971), with mainly smectitic mineralogy, exhibit a high coefficient of shrinkage and expansion leading to the development of deep wide cracks. They have been classified as vertisols, entisols, inceptisols and alfisols on the basis of their profile characteristic (Srinivasan et al., 1969). According to Srinivasan and Kompherst (1971) the vertic epipedon have (i) more than 25 cm thick layer, (ii) clay content exceeding 35 per cent, (iii) cracks at least 1 cm wide and 25 cm deep for some period and (iv) have strong prismatic and/or angular blocky structures with patchy slickensides and/or well-developed pressure faces below 10 cm depth. Retention of halic subgroup (Makin et al., 1969) to saline vertisols have been recommended by Srinivasan (1976). He suggested retention of ESP limit at 25 or more in the upper 30 cm crust, as proposed by Robinson (1971). This will place vertisols under a natric subgroup.

Due to deep cracking and self mixing, recognition of argillic or natric horizons in vertisols was ruled out. That is why the 'Soil Taxonomy' does not define any saline-alkaline vertisols. Instead salic and natric subgroups can satisfactorily include salinity and alkalinity conditions. Further, it is suggested that salic subgroup be used to include soils with salinity conditions not enough to qualify for a salic horizon (Sehgal et al., 1975; Bhargava et al., 1975).

No division of vertisols has been recommended in view of their high coefficients of expansion and shrinkage and consequent mixing and movement in surface and subsurface soils during the wet and dry cycles. Terms like natric, chromusterts, aquinatric chromusterts, sali-aquinatric chromusterts and salaquantric chromusterts can be used to further classify saline/alkaline vertisols.

Thus in the absence of a comprehensive soil legend for the salt affected soils, the 'Soil Taxonomy' system should, generally, be accepted for Indian soils. Addition of appropriate prepositions, mentioned earlier, should suffice for the present.

#### 5.6. CLAYS AND CLASSIFICATION OF CLAY MINERALS

There are no generally acceptable definitions for clays and clay minerals. The crystalline nature of clays was first confirmed by Hendricks and Fry (1930). Clays were defined as

natural minerals with high plasticity, small particle size and hardening on fire, or with at least two of such properties (Mckenzie, 1963). They generally predominate colloidal fraction of soils, rocks, etc. Thus their definition is very ambiguous. Gorbunov (1963) and Kulchitskii (1969) suggested that clay minerals should include only crystalline hydrous silicates with layered or chain-layered structures. Dorothy (1970) defined clay as a natural material of very fine texture, usually plastic when wet and hard and compact when dry. They consist of fine platy mineral particles ( $2\mu$  or less in size) and, sometimes, admixed with organic matter. The finest part of clay behaves as colloid. The fineness of grain size and other physical properties impart it stickiness as well as plasticity when wet.

Most clay minerals have layer-lattice structure (phyllosilicates) with  $\text{SiO}_4$  and  $\text{AlO}_4$  tetrahedron except for Palygorskite-Sepiolite group which have chain structure.

#### 5.6.1. Classification of Clay Minerals

The committee on the Clay Minerals Group, Mineralogical Society of Great Britain (1955), suggested division of crystalline clay minerals into chain and layer structures with 2 : 1 (triphormic) and 1 : 1 (diphormic) families. They were further divided on the basis of dioctahedral or trioctahedral structures. This scheme of classification has been widely accepted all over the world (Table-11).

Table-11 : Proposed classification scheme for the Phyllosilicates, including layer-lattice clay minerals.  
(As submitted by the AIPEA Nomenclature Committee to the International Mineralogical Association).

Type	Group (x=layer charge)	Sub-group	Species
	Pyrophyllite-talc x $\sim$ 0	Pyrophyllites talcs	Pyrophyllites talc
	Smectite or Montmorillonite	Diocahedral Smectites or Montmorillonite	Montmorillonite beidellite, nontronite
	Saponite x $\sim$ 0.5-1	Triocahedral Smectites or Saponites	Saponite Sauconite
2 : 1	Vermiculite x $\sim$ 1 to 1.5	Diocahedral Vermiculite Triocahedral Vermiculite	Diocahedral Vermiculite Triocahedral Vermiculite
	Mica*	Diocahedral micas	Muscovite, Paragonite
	x $\sim$ 2	Triocahedral micas	Biotite, Phlogopite
	Brittle Mica x $\sim$ 4	Diocahedral brittle micas Triocahedral brittle micas	Margarite Seybertite, Xanthophyllite, Drandisite
	Chlorite	Diocahedral Chlorites	--
	X variable	Triocahedral Chlorites	Pennine, clinochlore, Prochlorite
1 : 1	Kaolinite-Serpentine x $\sim$ 0	Kaolinites Serpentines	Kaolinite, Halloysite Chrysotile, Lizardite, Antigorite

\* The status of illite (or hydromica) and sericite is not clear.

### 5.6.2. Nomenclature of Clay Minerals

Kaolinite is used mainly for clay material that is low in iron. Kaolinite is the mineral that characterize most kaolins.

Kaolinite shows variation in stacking and the name mellorite was proposed for less crystallized material (Brindley, 1948). The polymorphs of kaolinite are designated by the symbols ITC, D, 2M2.

#### Halloysite

Berthier (1826), gave the term halloysite for the material found in pockets in Carboniferous limestone near Liege, Belgium. Halloysite is closely related to kaolinite. The name halloysite is given to lower hydration form and endellite to the higher hydration form.

The International Congress of Soil Sciences (1950) adopted the term halloysite for clay minerals, with X-ray peaks at  $7 \text{ \AA}$  in X-ray diffractograms in hydrated as well dehydrated form.

#### Montmorillonite

Montmorillonite is a group name for clay minerals with expanding lattice. It has high alumina with a slight replacement of  $\text{Al}^{3+}$  by  $\text{Mg}^{2+}$  and  $\text{Si}^{4+}$ .

## Vermiculite

Vermiculites have been classed with micas. It occurs as small particles on clay mineral. Vermiculites have expanding lattice, but unlike smectite, expansion is only limited. The composition of vermiculite is variable however, they contain considerable magnesium and iron. The main exchangeable cation is  $\text{Mg}^{2+}$ .

## Illite

Illite is characterised by a  $10 \text{ \AA}^0$  basal lattice on X-ray diffractogram with no expanding-lattice. Illite are of two types - trioctahedral and dioctahedral.

## Chlorite

The chlorite group represents green hydrous silicates with high ferrous iron and closely resembling the micas. Structurally, chlorites have inter-stratifications of biotite and brucite layers. They are important clay materials. They exhibit polymorphism (Bailey and Brown, 1962). The presence of mineral is determined with a  $14 \text{ \AA}^0$  peak in the X-ray diffractogram

### 5.7. STRUCTURE OF CLAYS

The common clay minerals are characterised by layered structures except for attopulgite group which are fibrous. Their structures have tetrahedrally and octahedrally coordinated cations forming composite layers (Fig. 14). The identification of layered clay minerals is mainly based on layer thicknesses or basal spacings which are approximately 7 Å, 10 Å, 15 Å and 14.5 Å. On this basis, layered clay minerals may be classified into four groups.

1. 1 : 1 (silica : alumina) two layer, Kandite group, including kaolinite, dickite haylloysite-anauxite.
2. 2 : 1 (three-layer) expanding minerals which expand between crystal units.
3. 2 : 1 (three-layer) silicates pyrophyllite-talc.
4. 2 : 2 type minerals.

#### 1 : 1 Type Minerals

Most members of kaolinite group consist of one octahedral and one tetrahedral layer, bound together. The sheet units continue along a and b axes and stacked along c-axis at about 7 Å distance. Kaolinite minerals with lower crystallinity also exist with highly disordered structure along b-axis, and random distribution of aluminium atoms.

Dickite and nacrite, though chemically identical to



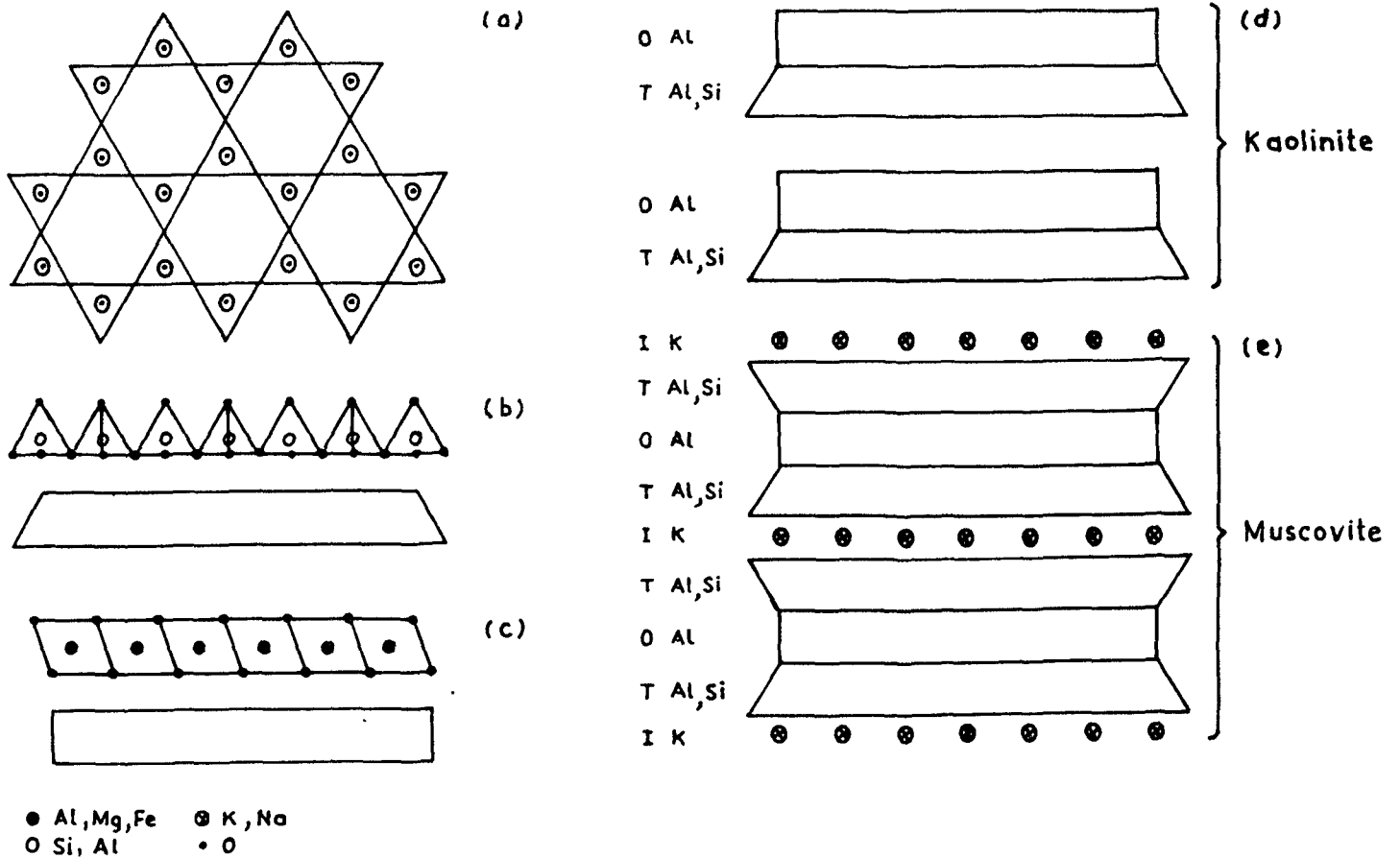


Fig. 14 – Structure of clay minerals (a) Top view of  $(\text{Si}, \text{Al})\text{O}_4$  groups in tetrahedral layer (b) Side view of tetrahedral layer and schematic representation (c) side view of octahedral layer and schematic representation (d) kaolinite structure, schematic representation (e) muscovite structure, schematic representation. T, tetrahedral layer; O, octahedral layer; I, interlayer cations.

kaolinite, have 2-layered, 6-layered monoclinic cells, respectively. In halloysite, due to layers of water molecules between its structural sheets, interlayer distance increase from  $7.2 \text{ \AA}$  to  $10 \text{ \AA}$ , due to stacking disorder. The water layer can be replaced by glycol increasing the interlayer distance from  $10 \text{ \AA}$  to  $11 \text{ \AA}$ . Other kandites are non-swelling.

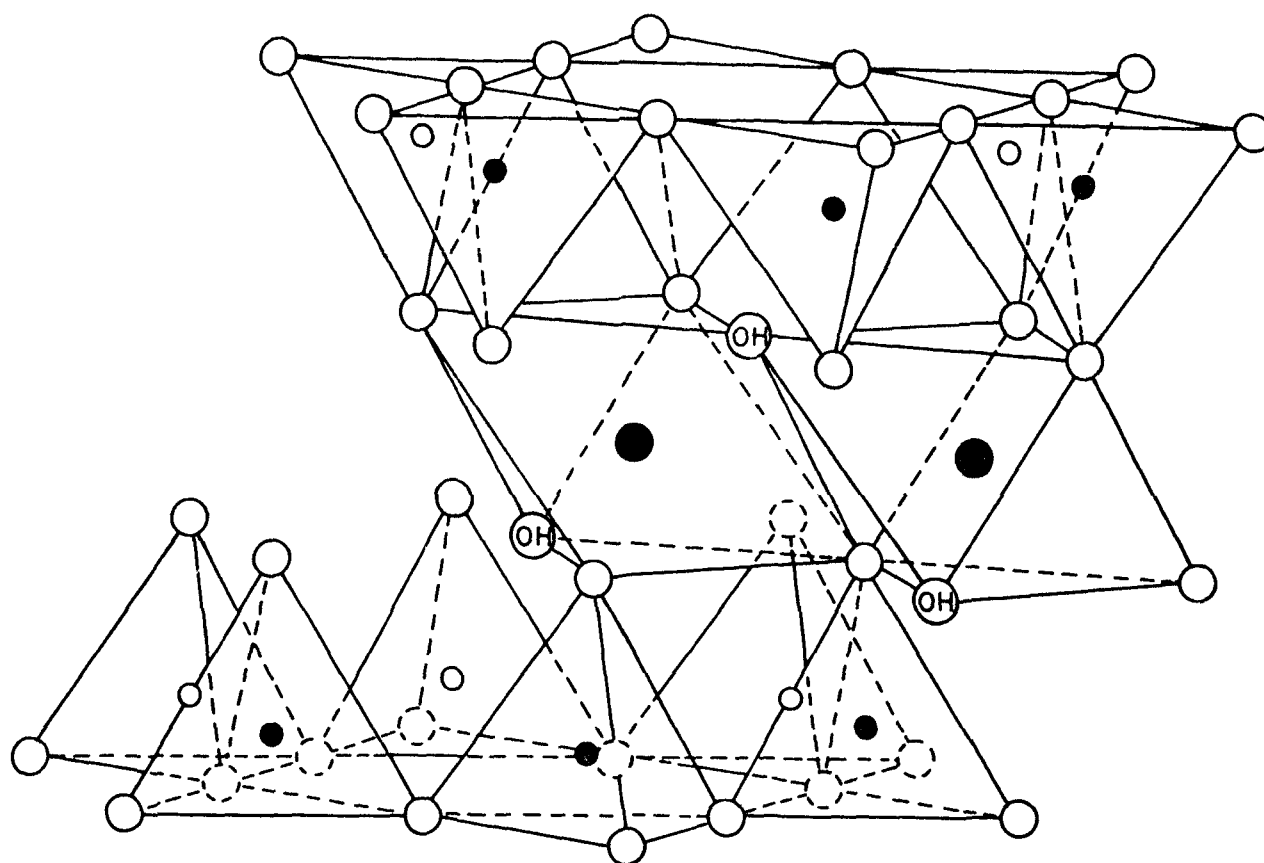
## 2 : 1 Type Expanding Minerals

Characterised by octahedral alumina sheet sandwiched between inward pointing tetrahedral silica layers, are two important clay mineral groups - montmorillonite and vermiculite.

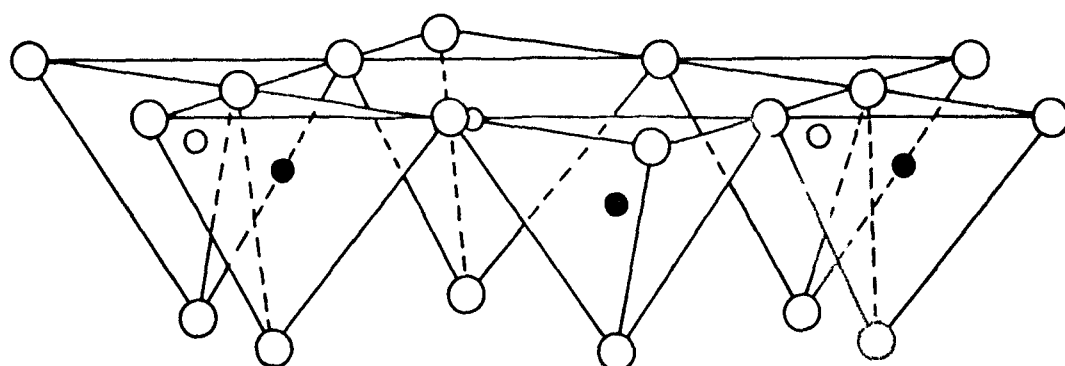
### Montmorillonite

The layers are continuous in a and b directions and are superimposed one above the other in the c direction. The inter-layer spacing  $d_{001}$  of montmorillonite is highly variable, the minimum being  $9.6 \text{ \AA}$ , in collapsed state (Fig. 15).

Under ordinary conditions, montmorillonite with exchangeable sodium ions has one molecular water layer and c-axis spacing of about  $12.5 \text{ \AA}$ , and those with calcium have two molecular water layers and c-axis spacing of about  $15.5 \text{ \AA}$ . The expansion properties are reversible unless the structure is completely collapsed.



Exchangeable cations  
 $n\text{H}_2\text{O}$



○ Oxygens    ○H Hydroxyls    ● Aluminum, iron, magnesium  
 ○ and ● Silicon, occasionally aluminum

FIG.15 DIAGRAMMATIC SKETCH OF THE STRUCTURE OF MONTMORILLONITE,  
 ACCORDING TO HOFMANN AND WILM (1935).

Montmorillonite crystal is generally, equidimensional, flaky which may become elongate, lath- or needle-shaped due to directional strain on the lattice caused by such substitutions as  $\text{Fe}^{2+}/\text{Mg}^{2+}$  for  $\text{Al}^{3+}$ . The most common montmorillonites are dioctahedral aluminous varieties.

### Vermiculite

Very much similar to smectite they exfoliate on heating. Their structure is similar to that of talc. The degree of swelling is considerably less for vermiculite than for montmorillonite. The cation adsorption capacity of vermiculite commonly exceeds that of all other silicate clays, including montmorillonite. They can absorb organic liquids between the layers.

### 2 : 1 Type Non-Expanding Minerals Illite

Illite belongs to an indefinite group called the hydrous mica. The structure comprise two Si-tetrahedral sheets with a central octahedral sheet.

The basal spacing of layers is unaffected by stacking irregularities and has a strong  $10 \text{ \AA}$  reflection. The most common polymorph of illites has disordered one-layered monoclinic cell. The unit cell of illite has a  $5.2 \text{ \AA}$ , b  $9.0 \text{ \AA}$ , z = 1.

Because of little or no interlayer water and organic liquids, the basal reflections are unaffected by heating even up to 500°C.

## 2 : 2 Type Minerals

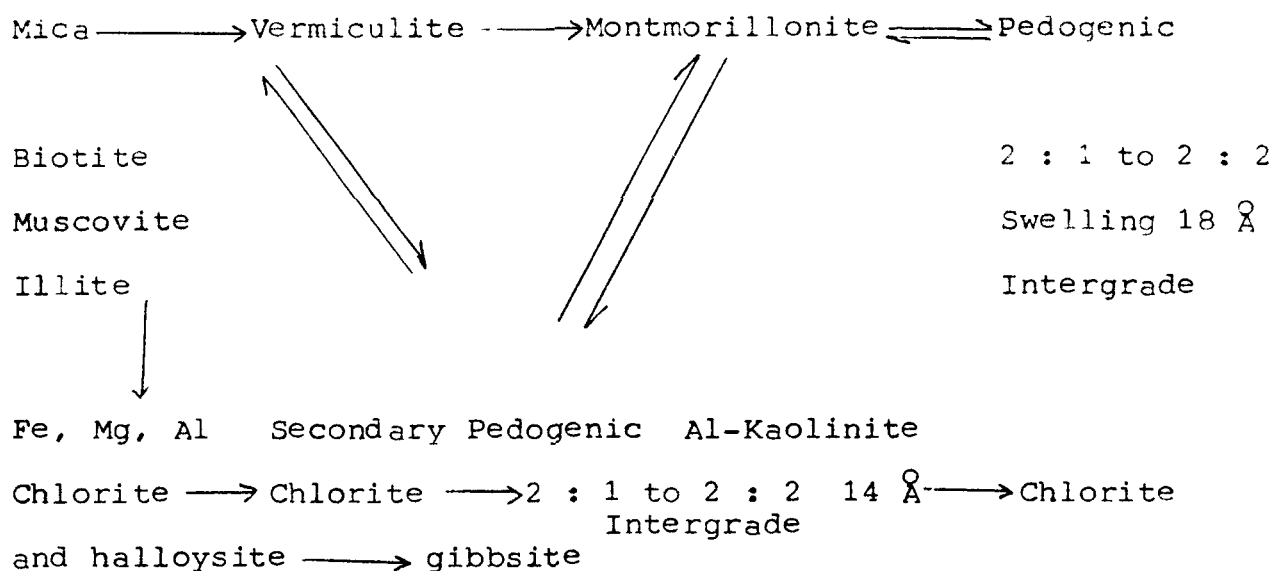
Chlorites have alternate talc-like and brucite-like layers. The cell parameters of chlorites vary with chemical composition. Substitution of  $\text{Al}^{3+}$  for  $\text{Si}^{4+}$  and  $\text{Mg}^{2+}/\text{Fe}^{2+}$  reduces the basal spacings. Substitution of  $\text{Fe}^{2+}$  or  $\text{Mn}^{2+}$  for  $\text{Mg}^{2+}$  increased both a and b. The basal X-ray reflections are very useful guide to composition.

### 5.8. FORMATION OF CLAY MINERALS IN SOIL

The clay minerals which are hydrous silicates or aluminosilicates are the products of weathering of primary minerals. Their crystallization from solutions has also been reported (Keller, 1954).

Mackenzie (1965) and Millot (1970) gave three modes of origin of clays, viz., (i) Detrital (ii) Transformation or alteration and (iii) Neoformation or synthesis. More than one process may be operative with different degrees of dominance. During physical weathering inheritance is dominant, whereas, during chemical weathering second and third processes predominate.

The various weathering reactions involved in the formation of clays in soils are as follows :-



Under dry (hot or cold) conditions feldspar and ferromagnesian minerals occur in significantly large amounts in soils. A close relationship also exists between the clays found in the parent material and in the soil, e.g., igneous rocks are certainly known to contain clay minerals in vesicles (Mitchell, 1954; Makenzie, 1957).

When chemical weathering is insignificant the mineralogy of soils is inherited from the parent material, e.g., presence of kaolinite in desert soils (Sehgal, 1970; Yahia, 1971) and universal occurrence of quartz and feldspar in most soils (Mackenzie, 1965; McNeal, 1966; Meelu and Van Ruymbeke, 1969; Gupta, 1964; Sehgal, 1970-72; Sehgal and DeConinck, 1973).

The transformation of clay, without involving structural change, depends on a number of factors like topography, climate and parent material.

Poorly drained soils favour clay formation like montmorillonite from biotite (Barshad, 1967) and moderate drainage favours decomposition of biotite to vermiculite (Walker, 1949) and illite to 3-layer non or montmorillonite.

In humid tropical climate kaolinite is a dominant mineral. The following alteration sequence was observed by Hseung and Hsu (1964) :-

Illite	Illite, vermiculite	Illite, vermiculite,
Kaolinite	Kaolinite, vermiculite	Kaolinite,
		gibbsite.

The following sequence of alteration in layer silicates was observed in the soils of Indo-Gangetic plains.

	( Illite	Montmorillonite
Illite	(	
	( Chloritised montmorillonite (Impeded	
	(	
	( drainage)	
Illite		
	( Vermiculite	Chloritised vermiculite +
Vermiculite	(	
	( Kaolinite in traces (normal drainage)	

The genesis of trioctahedral Al-chlorite follows the sequence (Kato, 1965).

Biotite	hydrobiotite	trioctahedral Al-
Vermiculite		trioctahedral Al-chlorite.

The most common alteration sequence of micas is as follows :-

Mica	intermediate stage	vermiculite
montmorillonite		

Thus kaolinite is formed in acidic environment and montmorillonite due to impeded drainage or excessive evaporation. With increased leaching, montmorillonite may alter to kaolinite.

Illite, also known as hydrous mica, is similar structurally to montmorillonite in that partial charge within the layers are neutralized by interlayer cations. Although illite is typically developed in deep-sea sediments, it also forms on land under certain conditions.

Mg-rich vermiculite is the common weathering product of mafic rocks, whereas, Al-rich vermiculite is a common weathering product of micas. The weathering product chart depicts the development of clay sequence (Fig. 16).

The clay-sized minerals together with representations of some of the species, and hybrid minerals intermediate between well defined clay minerals species, can also occur and add materially to complexity of soil mineralogy.



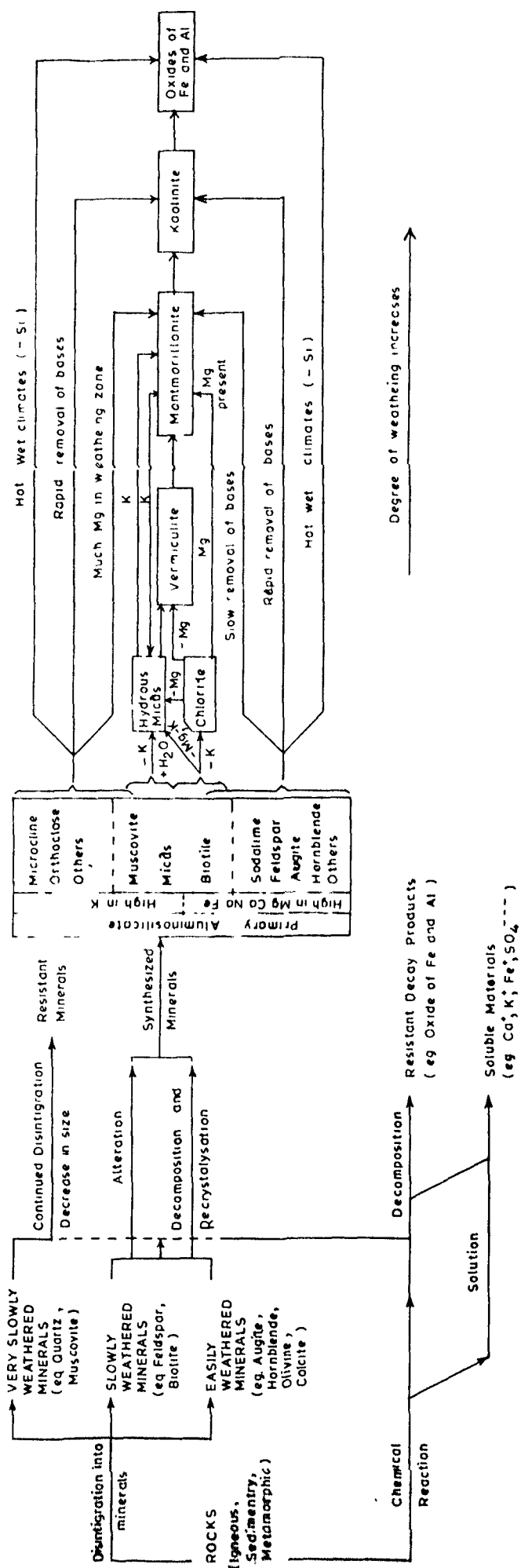


FIG-16. Primary minerals — Weathering products — Clay sequence model  
( After Brady 1974 )

## CHAPTER - VI

MECHANICAL ANALYSIS, MINERALOGY AND  
MICROMORPHOLOGY OF THE 'REH' SOILS

Results of the systematic analysis of Landsat images (visual interpretation) are given in Tables-12 and 13 in terms of some basic elements such as colour, tone, texture, drainage, shape, size, position, shadow and pattern.

The entire area is under alluvial deposits which are newer as well as older and mostly consist of sand, silt and clay.

6.1. SALINE AND ALKALINE SOILS

Saline and alkaline areas were delineated on the map on the basis of image characteristics and field checks. They were differentiated into two kinds :-

Saline	AS <sub>1</sub>	
Alkaline	AS <sub>2</sub>	(Fig. 17)

6.2. MORPHOLOGICAL AND MECHANICAL ANALYSIS

The morphological and mechanical characteristics are summarised in Tables-14 and 15. Salient features of soils from various localities are presented as follows :-

FIG.17- MAP OF ALIGARH DISTRICT SHOWING DISTRIBUTION OF MAJOR  
REH PATCHES BASED ON LANDSAT IMAGERY 1981-82

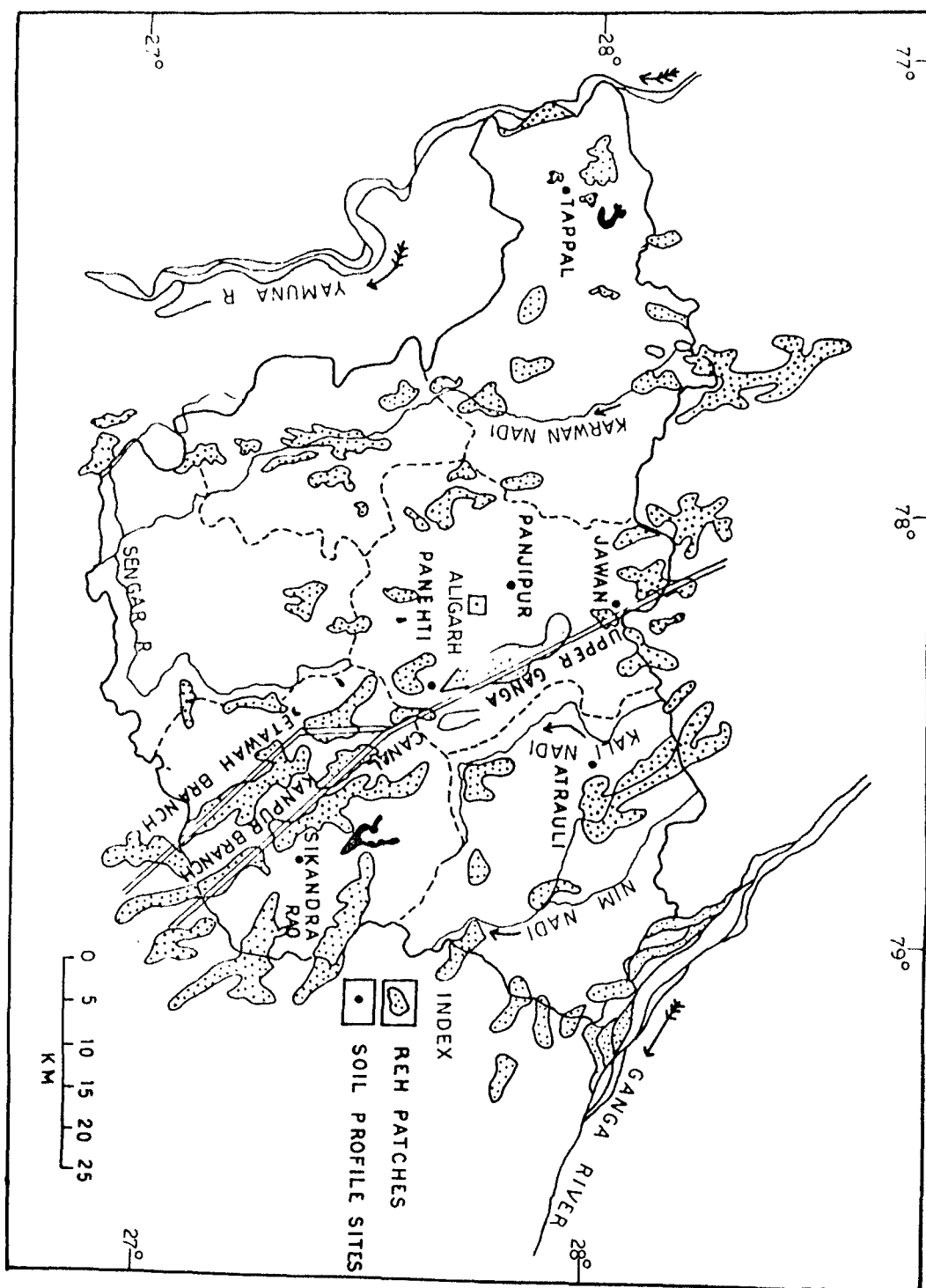


Table-12 : Soil type identified from Landsat Imagery.

Lithology	Correlation
1. Ganga Khadar	
2. Eastern Uplands	
3. Central Lowlands	
4. Western Uplands	Alluvium
5. Trans-Yamuna Khadar	
6. Ganga Khadar	

Table-13 : Geological, geomorphological and hydrogeological features on Landsat imagery (visual interpretation of MSS, FCC Bands 4, 5 and 7).

Geological/Geomorphic Features	Degree of Clarity
Rivers/streams/canals	Picked up very clear
Soil moisture	Poor/very clear
Water bodies (tanks, pools)	Clear
Alluvium	Light tone/clear
Salt efflorescence	Light tone/clear
Landuse	Not clear
Minor Channels	Could not pick up
Vegetation	Not clear
Settlement	Not clear

### Tappal

The soils at Tappal have matrix ranging in colour from light brown to dark yellowish brown. The texture of the soils vary from sandy loam to clay with a 'kankar' (calcium carbonate) zones at a mean depth of 125.3 cm. Vast tracts of land is covered with white salt ('Reh') efflorescence. The carbonate nodules increase with clay contents downward (Table-14).

### Jawan

The soils at Jawan are yellow to dark grey in colour and texturally loamy sand to silty clay loam. Tiny iron nodules are frequently found in the entire profile. A 'Kankar' zone occurs at intermediate depth (70 cm to 94 cm). The area, in general, is flat but at places slightly inundated. Vast 'Reh' tracts appear during dry season. The soils are massive to blocky (Table-14).

### Panjipur

At Panjipur the soils range from yellow to yellowish black in colour. The soils are from sandy loam to clayey in texture. Two kankar zones have been noted, one shallow near the surface (from 86 cm to 135 cm) and the other somewhat

Table-14 : Morphological Characteristics of 'Reh' soil profiles of Aligarh District.

Soil Profile Site	Topography	Depth of water table	Depth in cm	Colour	Drainage	Vegetation	Salts Crust	Effervescence
Tappal	Slopy Frequent inundation	0-110 cm	0-48.1 48.1-60.5 60.5-90.3 90.3-125.3 125.3-130.1	Light brown Dark brown Yellowish Yellow Dark yellow brown	Poor	Alhagi	Vast tracts of Reh ----- Kankar -----	Effervescence with dil. HCl.
Jawan	Flat and Depressed	650-700 cm	0-30 30-70 70-94.1 94.1-110 110-129	Yellow Grey whitish yellow Yellow grey Dark grey	Poor	Alhagi	Vast tract of Reh with concret- ion of CaCO <sub>3</sub> +Fe	Effervescence with dil. HCl.
Panjipur	Depressed	500-745 cm	0-5 5-86 86-135 135-185 185	Yellow Yellowish Yellowish grey Yellowish Yellowish grey	Poor	Alhagi	Vast tracts of Reh with CaCO <sub>3</sub> concretions	Effervescence with dil. HCl.
Atrauli	Flat and slightly depressed	170-300 cm	0-26 26-39.8 39.8-45.2 45.2-59.0 59.0-105	Whitish yellow Yellow Grey Grey	Imperfect	Alhagi Pseudo Alhagi	Vast tracts of Reh	Effervescence with dil. HCl.
Panhethi	Depressed	180-290	0-10.3 10.3-51.2 51.2-80.9 80.9-121.3 121.3	Dark grey Yellow Yellowish grey Grey Yellow	Poor	Alhagi Pseudo Alhagi	Vast tracts of Reh with CaCO <sub>3</sub> concretions	Effervescence with dil. HCl.
Sikandra Rao	Depressed	175	0-20.0 20.0-41.8 41.8-65.3 65.3-83.0 83.0-121.8	Yellowish grey Yellow Yellowish grey Grey Dark grey	Poor	Alhagi Pseudo Alhagi	Vast tracts of Reh with CaCO <sub>3</sub> concretions	Effervescence with dil. HCl.

deeper at about 185 cm. The nodules with peculiar outgrowths in the latter are locally called as 'Bichhwa kankar' (Scorpion-shaped nodules), an appropriate description of shape. The upper clay zones have long cylindrical (1/4 mm diameter) kankars. The iron nodules are completely absent (Table-14).

#### Atrauli

These soils are whitish yellow to grey in colour and are sandy to silty clay loam in texture. Vast tracts of 'Reh' appear during dry season. Occasionally,  $\text{CaCO}_3$  nodules are present. The area gets water-logged during the rainy season. The proportion of silt and clay increases with depth (Table-14).

#### Panhethi

The soils at Panhethi are dark grey to yellowish grey in colour. Texturally, they are loamy sand to silt loam. The zones of 'kankar' occur at 10.3 to 51.2 cm depth. Iron nodules are present, throughout. The area has permanent water logging and vast 'Reh' tract are seen during dry season (Table-14).

#### Sikandra Rao

The soils at Sikandra Rao are yellowish grey to dark grey in colour and from loam to silty clay loam in texture.



The entire block remains water-logged due to concave topography and poor drainage. The carbonate nodules ('kankar') intermixed with silty clay loam occur at 65-83 cm depth (Table-14).

#### Mechanical Separates (Table-15)

With increasing depth, the sand content in the profiles at Tappal ranged from 47.1 to 20.5 per cent. In Jawan profile, it ranged from 81.3 to 17.8 per cent. At Panjipur, the profile shows sand content from 72.1 to 27.3 per cent. At Atrauli, it varies from 70.9 to 17.5 per cent, while at Panhethi and Sikandra Rao they range from 80.1 to 25.4 per cent and 75.2 to 11.1 per cent, respectively.

The silt content in profiles at Tappal ranged from 52.8 to 33.1 per cent, and in Jawan from 54.8 to 10.2 per cent. The Panjipur profiles have 52.3 to 10.6 per cent of silt content, whereas at Atrauli it ranges from 52.9 to 15.5 per cent. In Panhethi the content of silt varies from 54.3 to 11.4 per cent and at Sikandra Rao from 54.0 to 12.8 per cent.

The clay contents recorded at various profiles are - Tappal 72.3 to 14.2 per cent, Jawan 58.8 to 8.5 per cent, Panjipur 55.1 to 12.3 per cent, Atrauli 27.1 to 13.6 per cent, Panhethi 20.6 to 12.1 per cent and Sikandra Rao 38.4 to 12.0 per cent.

PLATE 2

- a      Quartz rounded fragments showing corroded outline and inclusion.
- b      Muscovite. Elongated grain showing well-developed cleavage and cloudiness due to partial alteration to clay mineral.
- c      Orthoclase. A partly altered grain.
- d      Microcline. With well developed M-twinning.
- e      Plagioclase. Showing well developed polysynthetic twinning. The grain is partially altered with an inclusion (colourless).

+ Nicol x 25



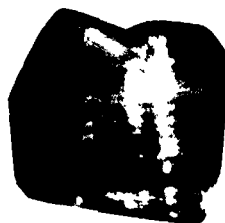
(a)



(b)



(c)



(d)



(e)

PLATE 2 LIGHT MINERAL ASSEMBLAGES IN 'REH' SOILS OF  
ALIGARH DISTRICT

**Table-15 : Mechanical Analysis of 'Reh' or 'Usar' Soils  
of Aligarh District.**

Depth in cm	Percentage of sand	Percentage of silt	Percentage of clay	Textural Class
<u>TAPPAL</u>				
0-48.1	47.1	38.3	14.6	Sandy loam
48.1-60.5	42.9	52.8	14.2	Silt loam
60.5-90.3	20.5	7.2	72.3	Clay
90.3-125.3	-----	Kankar	Zone	-----
125.3-140.1	33.1	50.3	16.6	Silt loam
<u>JAWAN</u>				
0-30	17.8	53.5	28.7	Silty clay loam
30-70	28.1	51.5	20.4	Silt loam
70-94.1	27.7	13.7	58.8	Clay and kankar
94.1-110	17.9	54.8	27.3	Silty clay loam
110-129	81.3	10.2	8.5	Loamy sand
<u>PANJIPUR</u>				
0-5	34.9	10.6	54.1	Clay and kankar
5-86	27.3	52.3	20.4	Silt loam
86-135	-----	Kankar	Zone	-----
135-185	67.8	16.5	15.7	Sandy loam
185--	72.1	15.6	12.3	Sand loam and kankar
<u>APRAULI</u>				
0-26	58.1	20.4	11.5	Sand loam
26-39.8	45.7	36.1	18.2	Loam
39.8-45.2	17.5	55.4	27.1	Silty clay loam
45.2-59	25.6	50.9	23.5	Silt loam
59-100	26.1	52.9	21.0	Silt loam and kankar
<u>PANHETHI</u>				
0-10.3	27.5	51.9	20.6	Silt loam
10.3-51.2	25.4	54.3	20.3	Silt loam and kankar
51.2-80.9	73.9	14.4	11.7	Sandy loam
80.9-121.3	80.1	11.4	8.5	Loamy sand
121.3	80.1	11.4	8.5	Loamy sand and clay lenses
<u>SIKANDRA RAO</u>				
0-20	52.3	31.5	16.2	Loam
20-41.8	40.1	38.9	21.0	Loam
41.8-65.3	11.1	51.5	38.4	Silty clay loam and kankar
65.3-83	16.9	54.0	29.1	Silty clay loam
83-121.8	75.2	12.8	12.0	Silty loam and kankar

Table-16.1 : Mineralogical Composition of 'Reh' Soils of Aligarh District (U.P.)

Depth (cm)	LIGHT MINERALS			
	Quartz	Muscovite	Orthoclase Microcline	Plagioclase
<u>TAPPAL</u>				
0.0-48.1	A	C	O	O
48.1-60.5	A	C	O	O
60.5-90.3	A	O	-	-
90.3-125.3	A	O	-	-
125.3-130.1	A	-	+	-
<u>JAWAN</u>				
0.0-30	A	C	P	O
30-70	A	C	O	+
70-94.1	A	C	-	-
94.1-110	A	P	-	-
110-129	A	O	-	-
<u>PANJIPUR</u>				
0.0-5	A	P	O	O
5-86	A	P	O	-
86-135	A	P	+	-
135-185	A	-	-	-
185	A	-	-	-
<u>ATRAULI</u>				
0.0-26	A	C	P	P
26-39.8	A	C	O	O
39.8-45.2	A	P	-	-
45.2-59.0	A	P	-	-
59.0-105	A	-	-	-
<u>PANHETHI</u>				
0.0-10.3	A	P	O	+
10.3-51.2	A	P	+	-
51.2-80.9	A	O	+	-
80.9-121.3	A	-	-	-
121.3	P	-	-	-
<u>SIKANDRA RAO</u>				
0.0-20	A	C	O	O
20-41.8	A	C	O	+
41.8-65.3	A	O	-	-
65.3-83.0	A	O	-	-
83.0-121.8	A	O	-	-

A = Abundant (65 Per cent)  
 C = Common (15-20 Per cent)  
 P = Present (Below one Per cent)  
 O = Rare (Below one Per cent)  
 + = Below one Per cent

Table-16.2 : Mineralogical Composition of 'Reh' Soils of Aligarh District (U.P.)

Soil Depth (cm)	Soil Type	HEAVY MINERALS									
		Quartz	Calcite	Pyrite	Chalcopyrite	Monoclinic Sulphide	Sphalerite	Staurolite	Ilmenite	Pyrite	Chalcopyrite
<u>FAHFAH</u>											
0.0-4.0	A	+	+	P	C	C	P	P	P	+	+
4.1-6.0	+	P	O	P	P	C	O	O	+	+	C
6.1-10.0	A	P	O	P	P	+	+	O	+	+	C
10.1-14.0	P	+	+	O	P	-	-	-	+	O	C
14.1-18.0	P	P	+	O	+	-	-	-	-	O	C
<u>SAHSAH</u>											
0-30	A	+	P	P	+	C	P	P	O	+	C
30-70	+	P	O	P	P	P	+	P	O	O	C
70-94.0	A	+	-	P	+	O	+	+	+	+	C
94.1-110	O	P	-	O	P	+	-	+	+	O	C
110-129	C	P	O	O	P	-	-	-	-	O	C
<u>PANJIPUR</u>											
0.0-5	A	C	P	C	P	P	P	P	P	+	C
5-36	A	C	P	C	P	P	P	P	-	+	C
36-135	A	C	P	P	+	+	+	-	+	+	C
135-145	C	C	O	-	+	-	+	+	+	P	C
145	C	-	-	-	O	-	-	-	+	+	C
<u>APRULI</u>											
0.0-26	A	A	C	O	P	P	O	+	P	P	C
26-30.0	A	C	+	P	P	+	O	+	+	+	C
30.1-45.0	+	P	P	O	O	+	+	+	+	O	C
45.1-70.0	C	P	O	O	+	O	+	+	+	O	C
70.1-100.0	P	P	+	+	+	-	-	+	-	-	-
<u>FAHFAH II</u>											
0.0-10.0	A	P	P	P	P	P	P	O	O	+	C
10.1-51.0	A	P	+	P	+	P	P	O	+	+	C
51.1-80.0	+	P	+	+	P	-	O	+	+	+	C
80.1-121.0	C	P	-	+	P	-	O	+	+	+	C
121.1	C	P	-	+	+	+	-	+	+	P	C
<u>SIKANDRA RAO</u>											
0.0-20	A	P	P	P	C	C	C	+	O	+	C
20-41.8	A	P	+	P	C	C	+	+	O	+	C
41.8-65.3	A	P	-	P	P	O	+	+	O	O	C
65.3-83.0	C	C	-	P	P	+	+	+	+	O	C
83.1-121.8	C	C	-	O	P	+	+	+	-	O	C
A = Abundant (65 Per cent) C = Common (15-20 Per cent) P = Present (5-10 Per cent) O = Rare (2-5 Per cent) + = Trace (one & below one Per cent) - = Absent (zero Per cent)											

A = Abundant (65 Per cent)  
 C = Common (15-20 Per cent)  
 P = Present (5-10 Per cent)

O = Rare (2-5 Per cent)  
 + = Trace (one & below one Per cent)  
 - = Absent (zero Per cent)

### 6.3. MINERALOGY OF THE 'REH' SOIL OF ALIGARH

#### 6.3.1. Light Minerals (Tables - 16.1 & 16.2)

The following light minerals were identified:-

1. Quartz
2. Muscovite
3. Orthoclase
4. Microcline
5. Plagioclase

#### 1. Quartz (Plate-2, Fig. a).

Quartz is one of the most widespread minerals ( > 65%) and is more or less uniformly distributed in all the soil profiles. It occurs, mainly, as single grains with shapes varying from angular, sub-angular, sub-rounded to even rounded. The grains are, usually, transparent and exhibit wavy extinction under the microscope. Larger grains are strongly pitted and marked by conchoidal fractures and coated with ferric oxide. They often contain inclusion of gas, liquids and needles of rutile and bleb-like inclusion of other minerals including micas. In conoscope they show uniaxial positive.

## 2. Muscovite (Plate-2, Fig. b )

Next to quartz, muscovite is the most abundant mineral marked by low relief and flaky habit. The interference colour is greysih in basal flakes but somewnat higher along the edges which curve up. It occurs in variable proportions in soil from 2 to 20 per cent at Tappal, 2 to 10 per-cent at Jawan and Panjipur, 5 to 20 per cent in Atrauli, 2 to 20 per cent in Panhethi and 5 to 10 per cent in Sikandra Rao area. It decreases downward indicating their decomposition to clay minerals (Pl. 2 ).

## 3. Orthoclase (Plate-2, Fig. c )

Orthoclase occurs only as single occasional crystals. The grains have angular to rounded shape and are twinned on Carlsbad law. Alteration is generally always present. The modal percentage in soils varies from 0 to 5 in Tappal, 5 to 10 in Jawan, 1 to 5 in Panjipur, 0 to 10 in Atrauli, 1 to 5 in Panhethi and 0 to 5 in Sikandra Rao.

## 4. Microcline (Plate-2, Fig. d )

Microcline, too, occurs as occasional single, irregular, angular to rounded crystals with unmistakable cross-hatched twinning. The grains have low relief, weak birefringence and



are commonly altered to sericite and clay minerals. Their modal percentage in soils varies from 0 to 5 at Tappal, Jawan, Panjipur and Sikandra Rao and 0 to 10 in Atrauli and less than 1 in Panhethi.

#### 5. Plagioclase (Plate-2, Fig. e )

Plagioclase occur as angular, tabular, sometimes rounded grains. They have well developed cleavages, are colourless to white with multiple lamellar and Carlsbad twinning. The mineral is highly weathered and difficult to identify. It varies in soils from 0 to 5 per cent at Tappal, Jawan and Panjipur, from 5 to 10 per cent in Atrauli, 0 to 1 per cent in Panhethi and 0 to 5 per cent in Sikandra Rao (Pl. 2, Fig. e ).

#### 6.3.2. Heavy Minerals

Heavy minerals are useful in correlation and determination of provenance. A number of heavies were recorded from the soils of Aligarh. The following heavy minerals were identified (in order of decreasing abundance) :-

- (i) Tourmaline
- (ii) Zircon
- (iii) Garnet
- (iv) Biotite
- (v) Chlorite
- (vi) Kyanite
- (vii) Hornblende

(viii) Staurolite

(ix) Epidote

(x) Rutile

(i) Tourmaline (Plate-3, Fig. a )

Tourmaline is next only to quartz in abundance and occurs as ubiquitous minerals in the soils of Aligarh. Its shape varies from sub-rounded, rounded to elongate (prismatic) with basal fractures but no cleavage. Long crystals frequently have rhombohedral terminations and the basal partings. They are strongly dichroic. The pleochroic scheme is as follows :-

O = Deep bluish green

E = Pale yellow almost colourless

O > E

On the basis of pleochroism, three distinct varieties, viz., brown, green and blue, have been identified. Brown tourmaline, the most abundant of the three types, has commonly elongate prismatic form. The rounded basal grains appear isotropic and show uniaxial negative optic figure in conoscope. It shows inclusions of minerals and fluids. Their modal composition varies from 5 to > 60 per cent in Tappal, 21 to 65 per cent in Jawan, 15 to 65 per cent in Panjipur, 5 to 65 per cent in Atrauli and 15 to 65 per cent in Panhethi and Sikandra Rao.

PLATE 3

- a      Tourmaline. Euhedral, sub-rounded, prismatic crystals with fluid and mineral inclusion. (+ nicol x 30).
- b      Zircon. Rounded to sub-rounded grains with high relief. (Ordinary light x 25).
- c      Garnet. Showing radial fractures and sub-rounded shape. (Ordinary light x 25).
- d      Biotite. Elongated cleavage fragment. (Ordinary light x 25)
- e      Chlorite. Angular grains, partly altered. (+ nicol x 10).
- f      Hornblende. Elongate crystal with well developed prismatic cleavage and oblique fractures. (+ nicol x 30).
- g      Kyanite. Prismatic crystal with two sets of cleavage. (+ nicol x 30).
- h      Epidote. Angular weathered crystal with cleavage. (+ nicol x 50).
- i      Staurolite. Showing partly developed cruciform twinning. (+ nicol x 50).
- j.      Rutile. Euhedral, prismatic, sub-rounded. (+ nicol x 50).
- k.      Ilmenite. Opaque, angular with white leucoxene (+nicol x 50)



(a)



(b)



(c)



(d)



(e)



(f)



(g)



(h)



(i)



(j)



(k)

PLATE 3 HEAVY MINERAL ASSEMBLAGES IN 'NEW' SOILS OF  
ALUMINUM DISTRICT

(ii) Zircon (Plate-3, Fig. b)

Zircon is one of the commonest among the heavy residues of Aligarh soils. It has euhedral to prismatic form with pyramidal terminations. The elongation index is high. Its relief is exceptionally high and colour somewhat brownish to pink. They often, exhibit some degree of zoning. Among the inclusions are large rod-shaped crystals and liquid. Some grains have 'dusky' appearance. The mineral varies from 5 to 65 per cent in the soils at Tappal, 5 to 10 per cent at Jawan, 15 to 20 per cent at Panjipur, 5 to 20 per cent at Atrauli, 5 to 10 per cent at Panhethi and 5 to 20 per cent at Sikandra Rao.

(iii) Garnet (Plate-3, Fig. c)

Garnet is another important constituent of the heavy residues. Its colour varies from colourless, reddish to pale brown. The latter being the dominant ones. The mineral shows wide variation in shape from rounded and subrounded to, occasionally, angular and sub-angular. When well rounded the grains surface is marked by percussion scars. Others are etched into a 'massive' of facets, or pits. A few acicular inclusions, perhaps of rutile are seen. Their isotropic character and high relief make them easily recognisable.

Garnet varies from 1 to 20 per cent in the soils at Tappal, 2 to 10 per cent at Jawan, 5 to 20 per cent at Panjipur, 1 to 10 per cent at Atrauli, Panhethi and Sikandra Rao.

(iv) Biotite (Plate-3, Fig. d)

Biotite occurs as cleavage flakes with jagged ends. The colour varies from straw yellow to deep brown, with marked pleochroism, the maximum absorption being when the cleavages are parallel to privilege vibration direction of Lower Nicol. Basal flakes are devoid of cleavage and pleochroism and are deep brown in colour. Biotite alters easily to chlorite, which may account for its total disappearance from many soils.

Its modal composition in soils varies from 2 to 10 per cent in Tappal and Jawan, 15 to 20 per cent in Panjipur, 1 to 10 per cent in Atrauli, 1 to 10 per cent in Panhethi and 2 to 10 per cent in Sikandra Rao.

(v) Chlorite (Plate-3, Fig. e )

Chlorite occurs as flat, rounded, irregularly cleaved flakes which are often twisted. The grains are marked by pale green colour, weak birefringence, micaceous habit and well centred pseudo-uniaxial interference figure. The ultra blue abnormal interference colour is very characteristic of chlorites.

Its modal composition in soils varies from 5 to 20 per cent at Tappal, 2 to 10 per cent at Jawan, 1 to 10 per cent at Panjipur, Atrauli, 1 to 10 per cent at Panhethi and 5 to 20 per cent at Sikandra Rao.

(vi) Kyanite (Plate-3, Fig. f )

Kyanite occurs as elongate angular or rounded grains with two sets of cleavages at right angles, one of them being parallel to the long direction of the crystals. It has a characteristic rectangular detrital form, controlled by the cleavages. Kyanite is generally colourless. The grains have broadly common orientation on account of which centred acute bisectrix figure is obtained in conoscope. The extinction angle,  $c \setminus z = 28^\circ$ . They show low birefringence, with frequent carbonaceous inclusions.

In modal composition it varies from 1 to 10 per cent at Tappal, 0 to 10 per cent at Jawan, 1 to 10 per cent at Panjipur, 1 to 5 per cent at Atrauli, 2 to 10 per cent at Panhethi and 2 to 20 per cent at Sikandra Rao.

(vii) Hornblende (Plate-3, Fig. g )

Hornblende occurs as elongate platy crystals with jagged edges due to prismatic cleavages. Some equidimensional grains with one set or two sets of cleavages (at  $\sim 60^\circ$ ) are seen.

Strong pleochroism from deeper to lighter shades of brownish to greenish characterise them. Occasional inclusions are seen. Alteration to chlorite is observed. The pleochroic scheme is as follows :-

X = Pale brown

Y = Light brownish greenish

Z = Dark green

$c \wedge z = 18^{\circ} \text{ to } 20^{\circ}$ .

The mineral has highly variable modal composition from 1 to 20 per cent in the soils at Tappal, Jawan and Sikandra Rao, 1 to 10 per cent at Panjipur and Atrauli and 1 to 10 per cent at Panhethi.

(viii) Stauroilite (Plate-3, Fig. h )

Stauroilite occurs in small amount. The grains are irregular, subangular to somewhat platy marked by hackly to subconchoidal fractures. Well-developed cleavages are seen. They have high relief. Most grains have straw yellow to brownish yellow colour and show distinct pleochroism in yellows. Inclusions of quartz and tourmaline are seen.

Its modal composition varies from 1 to 10 per cent at Tappal, Panjipur and Atrauli, 2 to 5 per cent at Jawan and 1 to 5 per cent at Sikandra Rao.



(ix) Epidote (Plate-3, Fig. i )

Epidotes are generally persistent to weathering and occur as single irregular grains. On the basis of pleochroism it is of 'pistacite' variety. They have high relief, variable extinction angle; strong birefringence and strong dispersion.

It varies from 0 to 10 per cent in the soils at Tappal, Jawan and Panjipur, 1 per cent at Atrauli, 1 to 5 per cent at Panhethi and 1 per cent at Sikandra Rao.

(x) Rutile (Plate-3, Fig. j )

Rutile occurs as elongate prismatic grains with rounded pyramidal ends. It is marked by longitudinal and oblique striations. It has reddish-brown colour. Geniculate and cordate twins are also found in many. It has very high relief.

Its modal composition varies from 1 to 5 per cent at Tappal and Jawan, 1 to 10 per cent at Panjipur, 1 to 5 per cent at Atrauli, Panhethi and Sikandra Rao.

#### 6.4. OPAQUE MINERALS

Opagues form bulk of the heavy crop. The opaque fraction is made up of the following mineral species :-

- (i) Magnetite
- (ii) Hematite
- (iii) Limonite
- (iv) Ilmenite
- (v) Leucoxene

(i) Magnetite

An important constituent, it occurs as angular, sub-rounded to rounded opaque grains. Fractured grains with irregular outlines are also observed. It is recognised by the silvery grey or shining bluish-black colours in reflected light under the microscope.

(ii) Hematite

Hematite also occurs as elongate, angular, rounded and sub-rounded grains. It is recognised by reddish-brown reflection under the microscope. Fractured grains with irregular boundaries are also present.

(iii) Limonite

Limonite frequently occurs as sub-rounded grains. It has brown and brownish yellow colour showing uneven and irregular surfaces.

(iv) Ilmenite

Ilmenite occurs as elongate, rounded, sub-rounded and angular grains. It is recognised by violet black colour in reflected light under the microscope. Some grains have conchoidal fractures.

(v) Leucoxene (Plate-3)

Leucoxene appears as rounded to sub-rounded grains sometimes pitted. It shows dead white in reflected light under the microscope.

## 6.5. DISCUSSIONS

The distribution of 'heavies' in the soil provide valuable pedological and sedimentological information. Distribution of the light and heavy minerals in the soils act as guides to evaluate the weathering status, mineral paragenesis and the fertility status.

### Light Minerals

The light mineral fractions studied in various soil profiles gave the following relative abundance :-

Quartz > muscovite > orthoclase, microcline > plagioclase

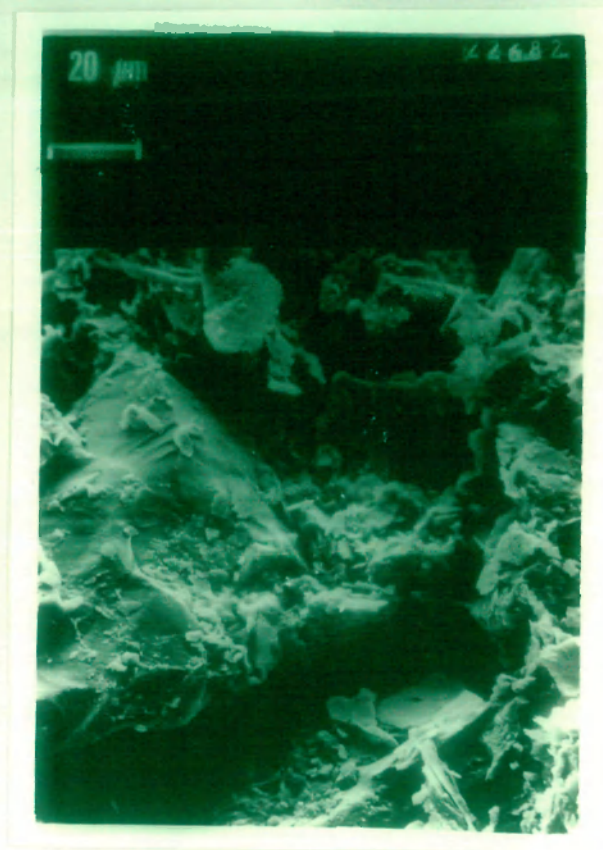
Quartz, the most dominant constituent, possesses the characteristics of fluvial and glacial conditions. The surface features of quartz, under SEM show moderate relief, subrounded to rounded form and even conchoidal fractures. These were regarded as features characteristic of glacial environment (Krinsley and Margdis, 1969; Singh, 1975). However, in the opinion of the author these provide no positive evidence of glacial features, on the contrary, it is suggested that the same can be explained due to fluvial activity under conditions of rapid flow (high energy conditions). This can explain not only the rounded form and smooth surface but also the conchoidal fracture due to mutual collision (Pl. 4a). Muscovite can be transported, derived from parent rocks, or even in situ, formed in soils due to chemical weathering. Well ordered micas have igneous or metamorphic provenance.

In the soil profiles at Tappal, Jawan, Panjipur and Atrauli micas are present in all the horizons. It may be concluded that in sandy and silty soils, under alkaline conditions, orthoclase and plagioclase feldspar alter to mica.

Because the Indo-Gangetic alluvium has been transported micas of both pedogenic as well as transported origins may be present. The rounded, angular to subrounded mica grains owe their shape to long transportation. But in other cases, alkaline

PLATE 4

- a        Scanning electron micrograph showing conchoidal fractured surface of quartz. Leaching effect is clearly made out.  
Reh soils of Aligarh district.
  
- b        Scanning electron micrograph showing small well developed rhombohedral crystals calcite in pore spaces in soils of Tappal and Jawan.



(a)



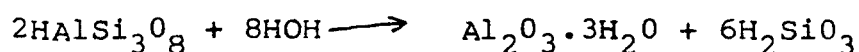
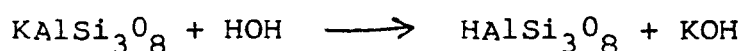
(b)

conditions together with scarcity of feldspars in soils are the indirect evidence of their pedogenic origin (Roonwal, 1967; Singh, 1975; Kaswala and Deshpande, 1986).

### Feldspar

Reh soils of Aligarh contain only a small number of feldspar grains, but they generally appear to be fresh. Microcline, orthoclase and plagioclase have all been recorded.

The scarcity of feldspars can be explained due to easy break down during chemical weathering in the presence of water. The lattice of feldspars are completely broken and strong bases like K, Na, and Ca are released which react with  $\text{Al}^{3+}$ ,  $\text{Si}^{4+}$  and  $\text{OH}^-$ , giving rise to colloidal aggregates that crystallize to form clay minerals, chiefly, kaolinite.



The stability of feldspars depends on the relative rates of decomposition and erosion. The scarcity of feldspars and presence of kaolinite is a strong evidence that suggests instability of feldspars in an alkaline medium. The freshness of feldspars (microcline, plagioclase) is indicative of mechanical disintegration. The remarkable freshness of feldspars in the Siwalik deposits and the Indo-Gangetic alluvium have been explained due to mechanical work of ice and frost on the parent rock (Meddlicot

and Blanford, 1879; Roonwal, 1967; Singh, 1975 and Manchanda et al., 1982).

The location of Tappal, Atrauli, Jawan, Panjipur, Panhethi and Sikanra Rao being very close to Ganga-Yamuna river system, quicker transportation during monsoon floods might account for these feldspars.

### Heavy Minerals

The frequency of distribution of heavy minerals in the 'Reh' soils of Aligarh district can be presented in the following order :

Tourmaline > Zircon > Garnet > Biotite  
 Chlorite > Kyanite > Hornblende >  
 Staurolite > Epidote > Rutile > Opaques.

The heavy mineral suites are made up of stable and unstable minerals. Quartz, the major constituent of the reh soils, owe their rounded form to high degree of abrasion. A few angular grains seem to have been brought down, in recent times, by the Himalayan rivers. Quartz, feldspars and micas seem to have been derived from igneous and metamorphic (gneisses and schists) rocks. The chlorite might be derived from the breakdown of the ferromagnesium minerals such as biotite (Table-17).

The heavy mineral species recorded from the 'reh' soils such as zircon, tourmaline, garnet, muscovite, and staurolite, indicate mostly metamorphic provenance and to a lesser extent



Table-17 : Detrital Mineral suites characteristic of source rock types.

---

Reworked Sediments

Barite	Leucoxene
Glaucconite	Rutile
Quartz (especially with worn overgrowths)	Tourmaline (rounded) Zircon (rounded)
Chert	
Quartzite fragments (orthoquartzite type)	

Low-Rank Metamorphic

Slate and phyllite fragments	Quartz and quartzite fragments (metaquartzite type)
Biotite and muscovite	
Feldspars generally absent	Tourmaline (small pale brown euhedral carbonaceous inclusions)

High-Rank Metamorphic

Garnet	Quartz (metamorphic variety)
Hornblende (blue-green variety)	Muscovite and biotite
Kyanite	Feldspar (acid plagioclase)
Sillimanite	Epidote
Andalusite	Zoisite
Staurolite	Magnetite

Acid Igneous

Apatite	Zircon (euhedral)
Biotite	Quartz
Hornblende	Microcline
Monazite	Magnetite
Muscovite	Tourmaline (small pink euhedral)
Sphene	

Basic Igneous

Anatase	Leucoxene
Augite	Olivine
Brookite	Rutile
Hypersthene	Plagioclase (intermediate)
Ilmenite and magnetite	Serpentine
Chromite	
Pegmatite	
Fluorite	Muscovite
Tourmaline, typically blue (indicolite)	Topaz
Garnet	Albite
Monazite	Microcline

---

igneous and sedimentary provenance. Minerals like garnet, chlorite, hornblende and staurolite are typical high rank metamorphic mineral (Pettijohn, 1957). Presence of kyanite suggests a high grade metamorphic provenance. Zircon, tourmaline could have been derived from gneisses and schists of the Himalayas. The predominance of green and brown varieties of tourmaline and some long prismatic crystals of zircon with high elongation are indicative of a parentage of granites, granitic gneisses and pegmatites (Smithson, 1939; Krynine, 1946; Okada, 1960; Pettijohn et al. 1972). These rock types abound in the crystalline axis of Himalayas. Widespread occurrence of epidote in the soils suggests a basic source (Krumbein and Pettijohn, 1978). The epidote suggests detrimental environment. The presence of rutile indicate acid igneous or crystalline metamorphic parentage.

The highly rounded quartz, tourmaline and zircon indicate long transportation and reworked sediments of Himalayas.

Thus, in conclusion, heavy mineral suites of Reh soils of Aligarh district, have been brought and deposited by Ganga river system from the Himalayan highlands into the Gangetic 'trough' (rift).

#### 6.6. MINERALOGY OF CLAYS

An attempt has been made to characterise and identify the clay material in saline-alkaline soil profiles.

The XRD and SEM are the two main tools employed in the study of carbonate and clay minerals.

**XRD Studies :** The oriented and powder diffractograms were analysed. The 'Reh' soils of Aligarh contain clay and other minerals like illite, chlorite, kaolinite, vermiculite, micas, calcite, feldspar and quartz.

**SEM Studies :** Application of SEM in the study of surface features of mineral grains, like quartz, kankars and clays of soils is strongly recommended. Secondary growths and various other types of depositions associated with salt efflorescence and capillary action are best studied by this means. The details are discussed in the proceeding chapter. The result of the studies is summarised in Tables-18 and 19.

Calcite is the dominant carbonate mineral with a peak at  $3.04 \text{ \AA}$ . Quartz ( $4.26 \text{ \AA}$ ), alkali feldspar ( $3.24 \text{ \AA}$ ) and plagioclase feldspar ( $3.19 \text{ \AA}$ ) have been detected in the top as well as in bottom layers of calcic zones (Figs. 18 AB, 19 AB, 20 AB, 21 AB, 22 AB, 23 AB).

Observation made with SEM coupled with those of XRD clearly showed that calcite is present in voids as secondary mineral due to capillarity action (Plate-4b).

The X-ray diffractograms of oriented clay samples indicate presence of illite, vermiculite, kaolinite and chlorite as the

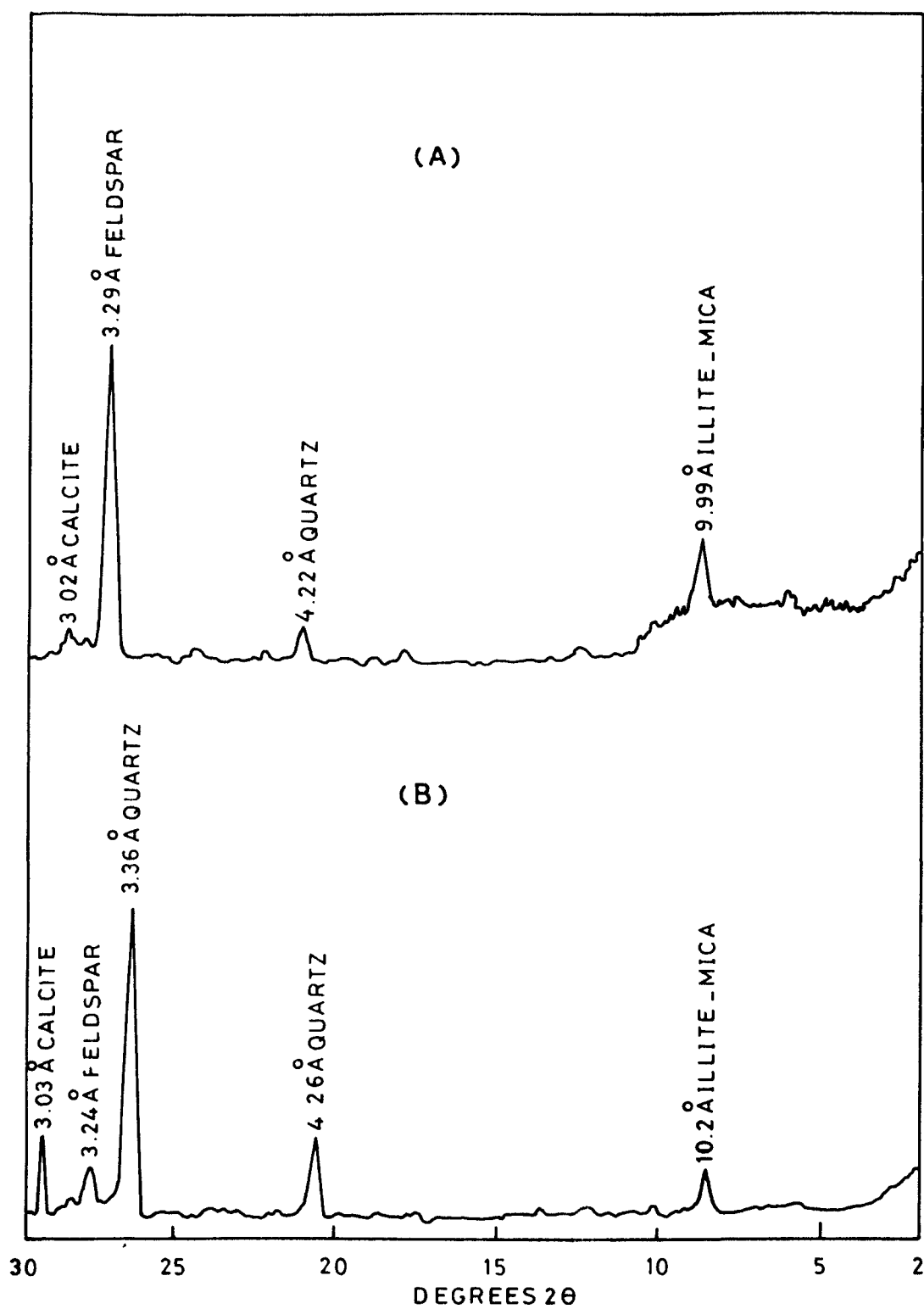


FIG-18 - POWDER X-RAY DIFFRACTOGRAM

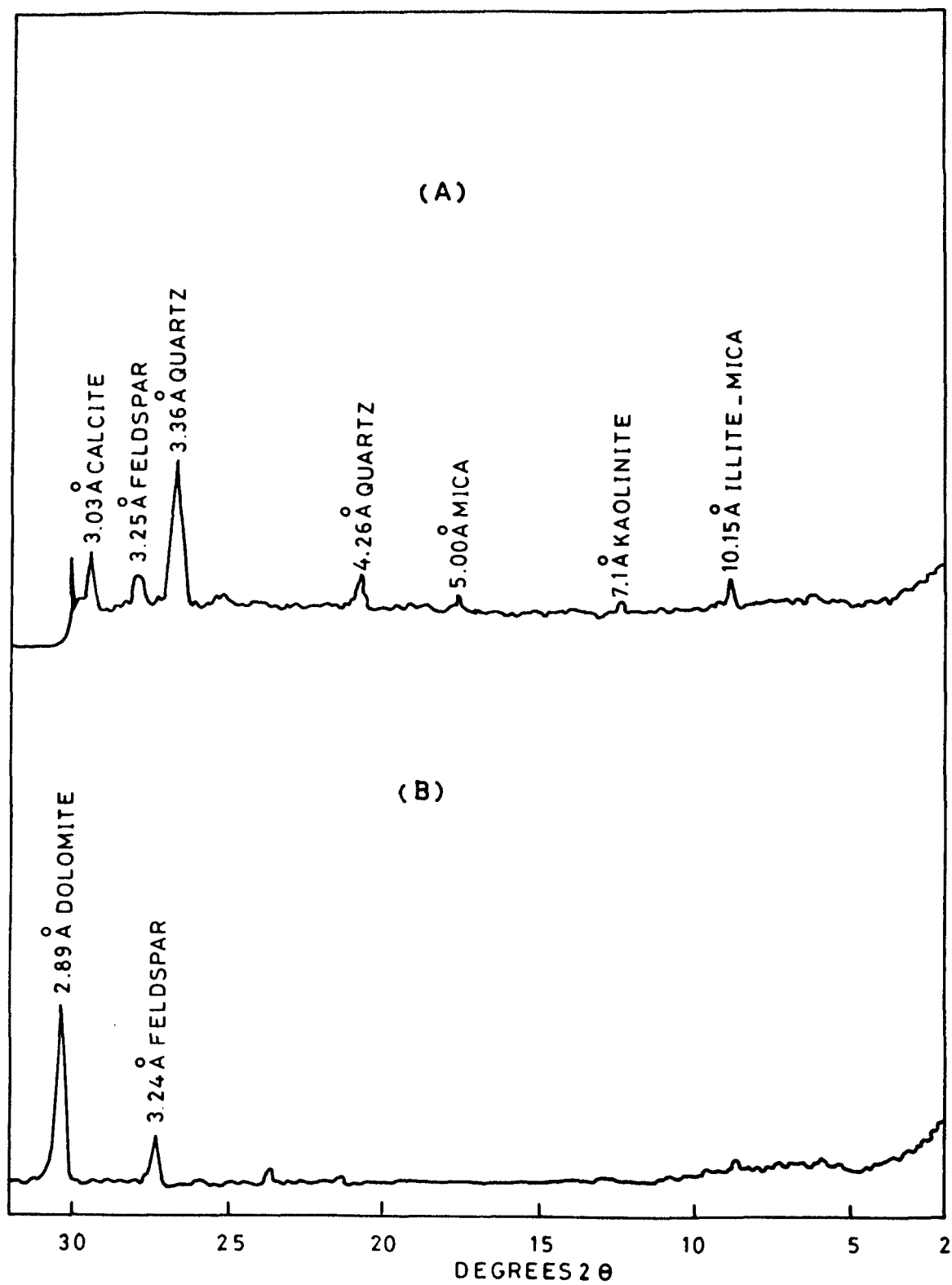


FIG. 19 - ORIENTED X-RAY DIFFRACTOGRAM

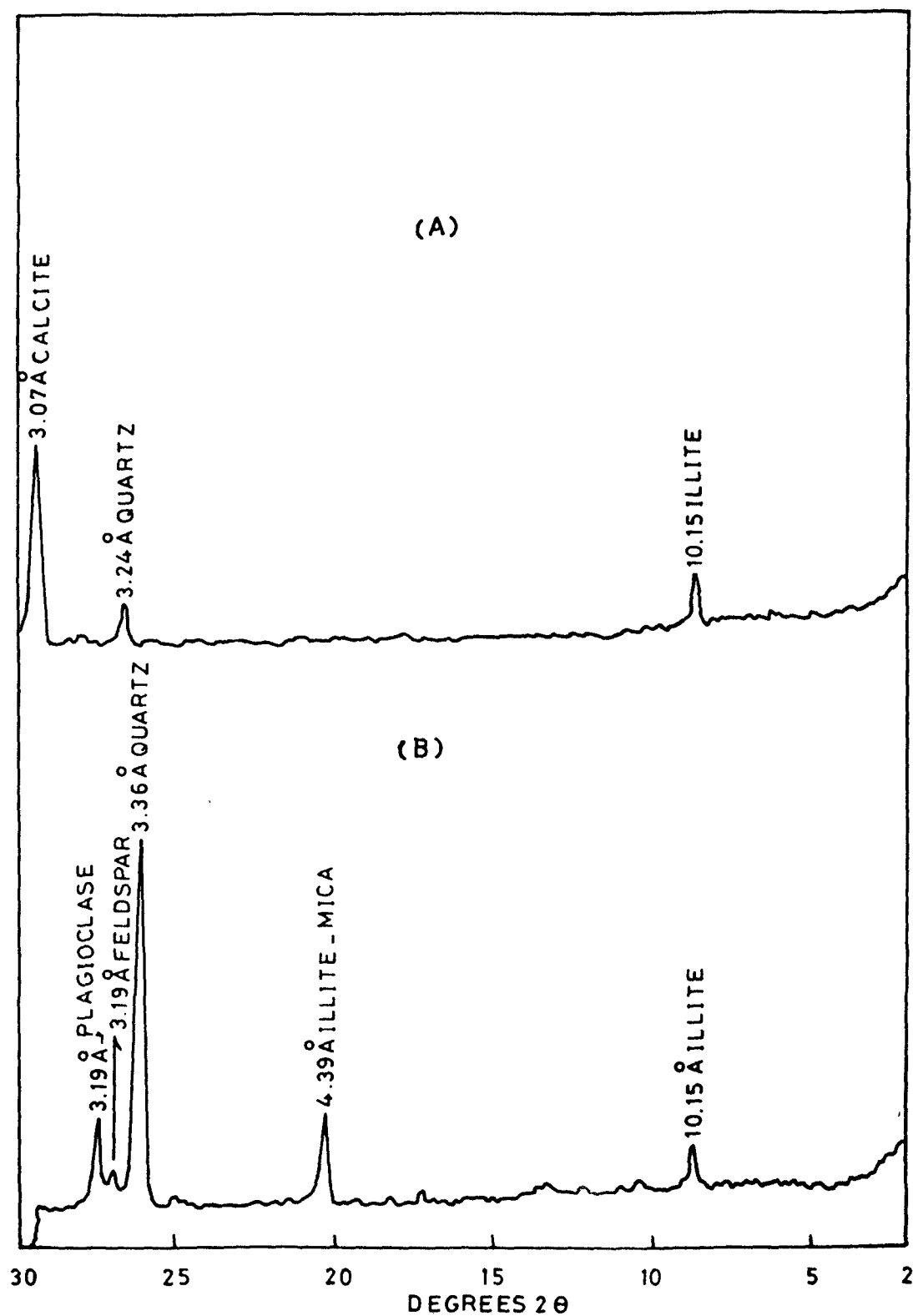


FIG. 20 - POWDER X-RAY DIFFRACTOGRAM

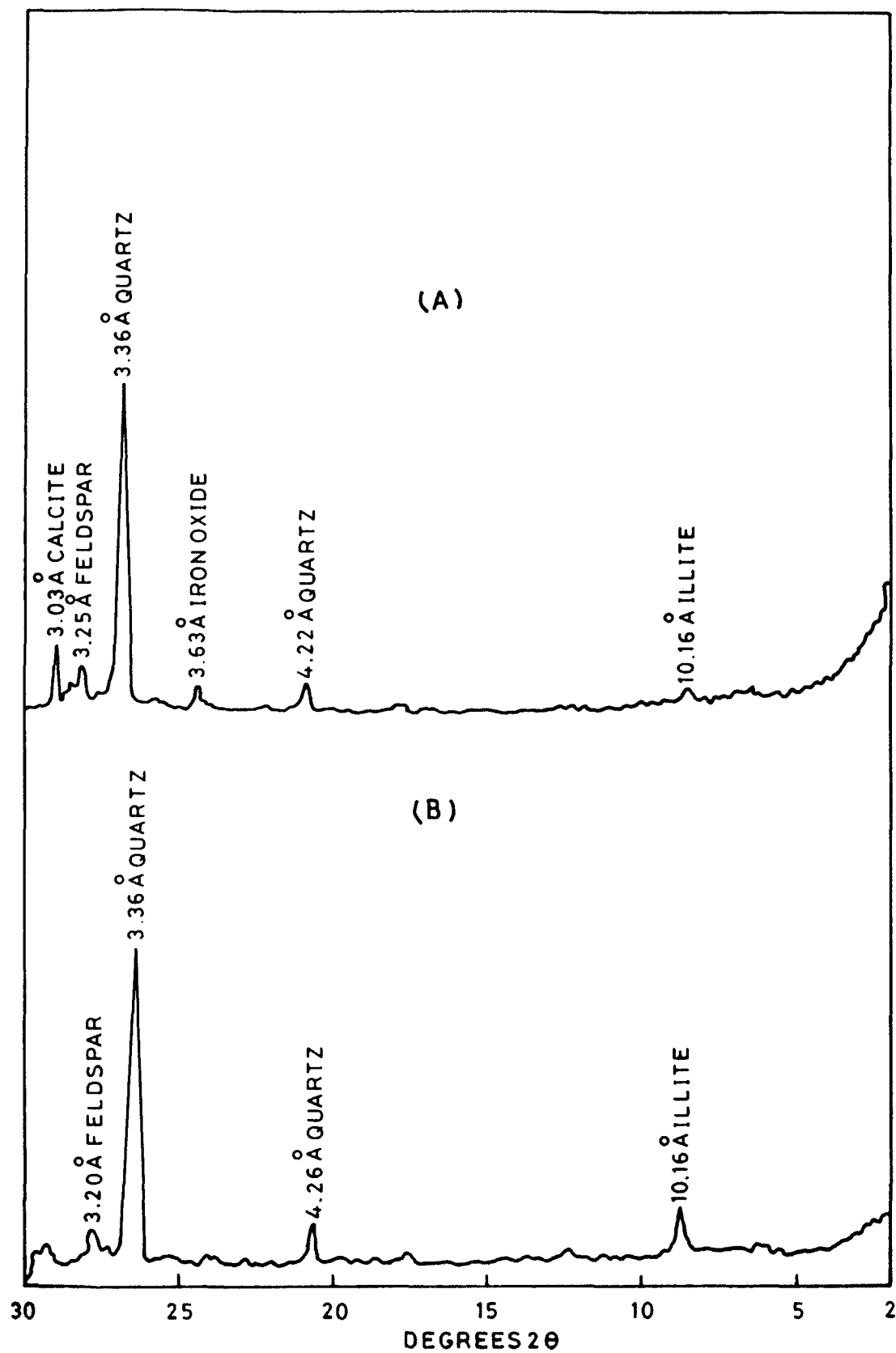


FIG. 21 — POWDER X-RAY DIFFRACTOGRAM



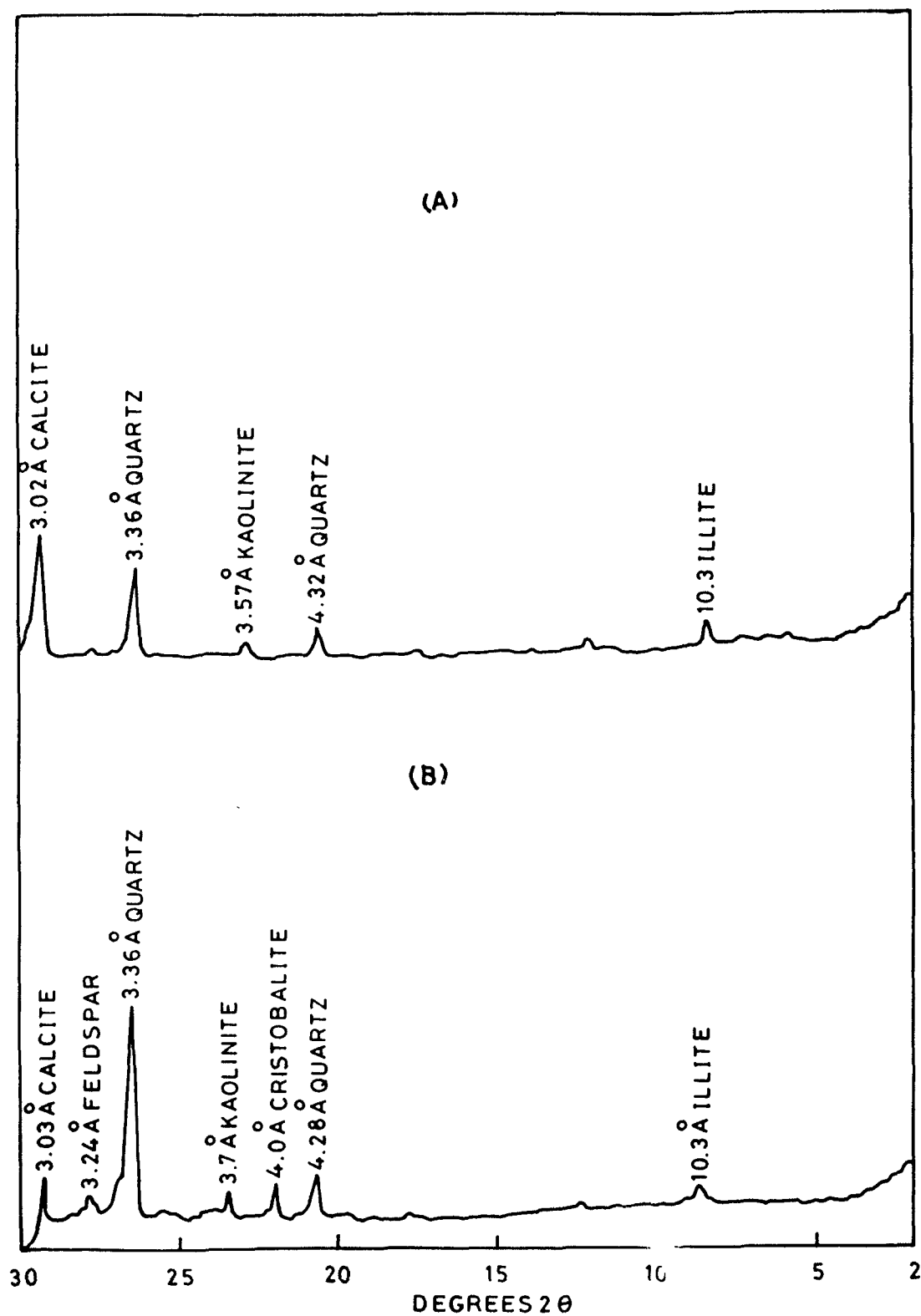


FIG. 22 - POWDER X-RAY DIFFRACTOGRAM

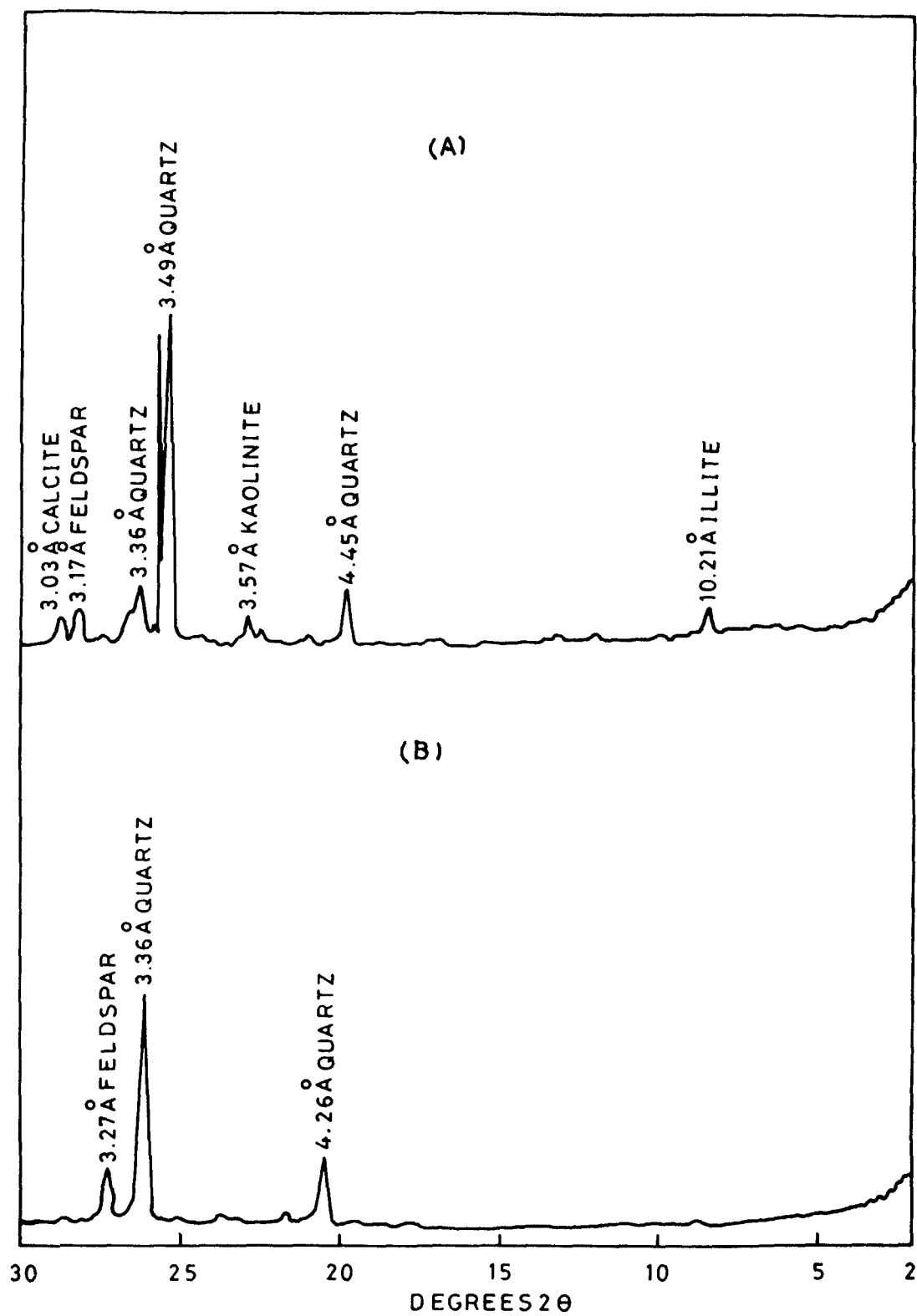


FIG-23-POWDER X-RAY DIFFRACTOGRAM

Table-18 : Characteristic Powder XRD Peaks of the minerals  
from the soils of Aliqarh.

Profile	XRD peaks of minerals identified				
	10 Å	4.26 Å	3.24 Å, 3.19 Å	3.04 Å	
Tappal	A	Illite	Quartz	Alkali, Feldspar and Plagioclase Feldspar	Calcite
	B	Illite	Quartz	Alkali, Feldspar and Plagioclase Feldspar	Calcite
Jawan	A	Illite	Quartz		Calcite
	B	Illite	Quartz		Calcite
Panjipur	A	Illite	Quartz	Feldspars	Calcite
	B	Illite		Feldspars	Calcite
Atrauli	A	Illite		Feldspars	Calcite
	B	Illite		Feldspars	Calcite
Panhethi	A	Illite		Feldspars	Calcite
	B	Illite		Feldspars	Calcite
Sikandra Rao	A	Illite		Feldspars	Calcite
	B	Illite		Feldspars	

Table-19 : Characteristic XRD peaks of Layer silicates in the soils of Aligarh area.

Location		Degrees 2 $\theta$		
		10 Å	10.5 Å, 14 Å	7 Å
Tappal	A	Illite	Vermiculite	Kaolinite
	B	Illite	Chlorite Vermiculite	Kaolinite
Jawan	A	Illite	Vermiculite	Kaolinite
	B	Illite	Vermiculite Chlorite	Kaolinite
Panjipur	A	Illite	Vermiculite	-
	B	Illite	Vermiculite	-
Atrauli	A	Illite	Chlorite	Kaolinite
	B	Illite	-	-
Panhethi	A	Illite	Vermiculite	-
	B	Illite	Chlorite	Kaolinite
Sikandra Rao	A	Illite	Chlorite	-
	B	Illite	Chlorite	-

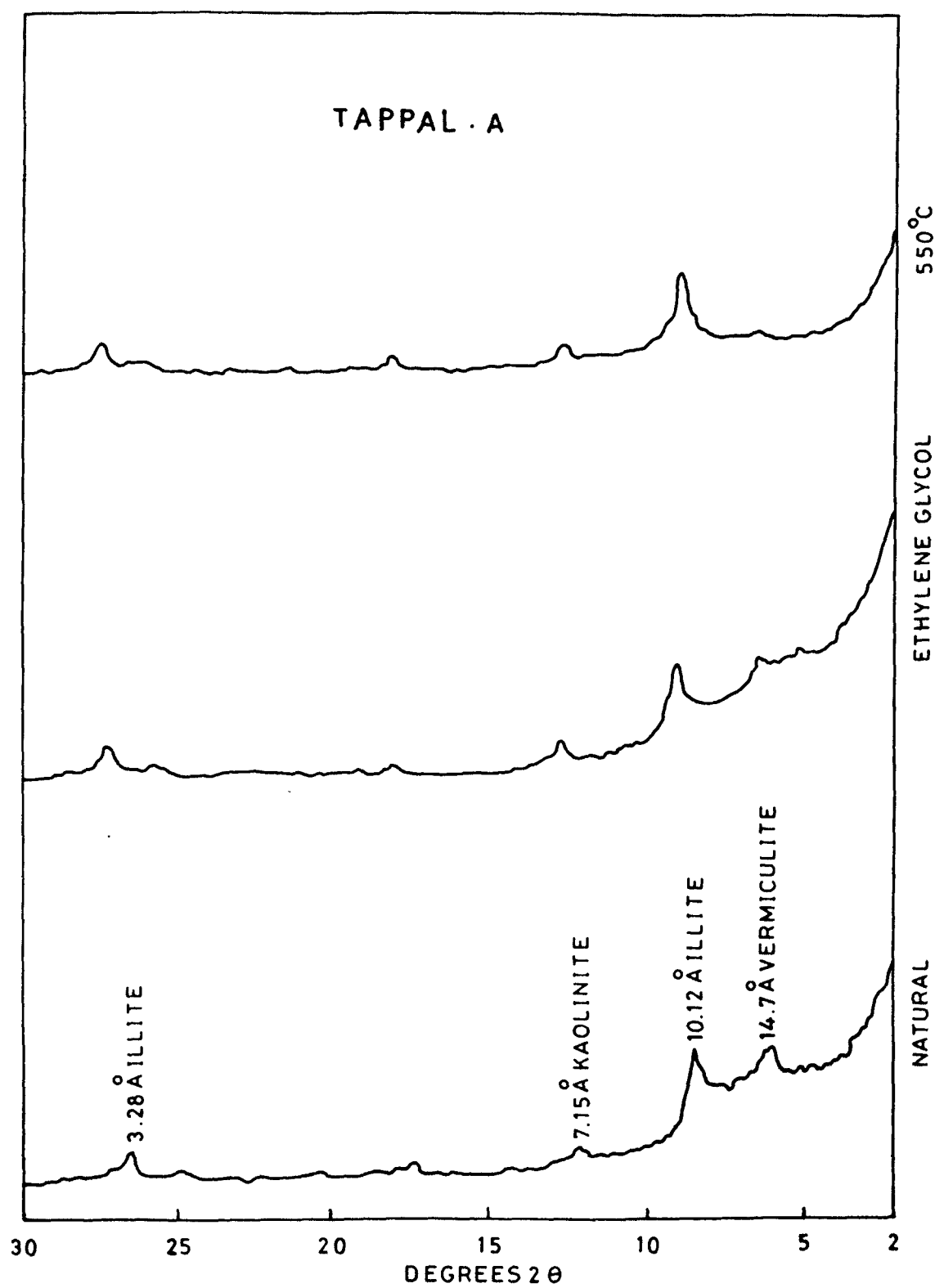


FIG-24-ORIENTED X-RAY DIFFRACTOGRAM

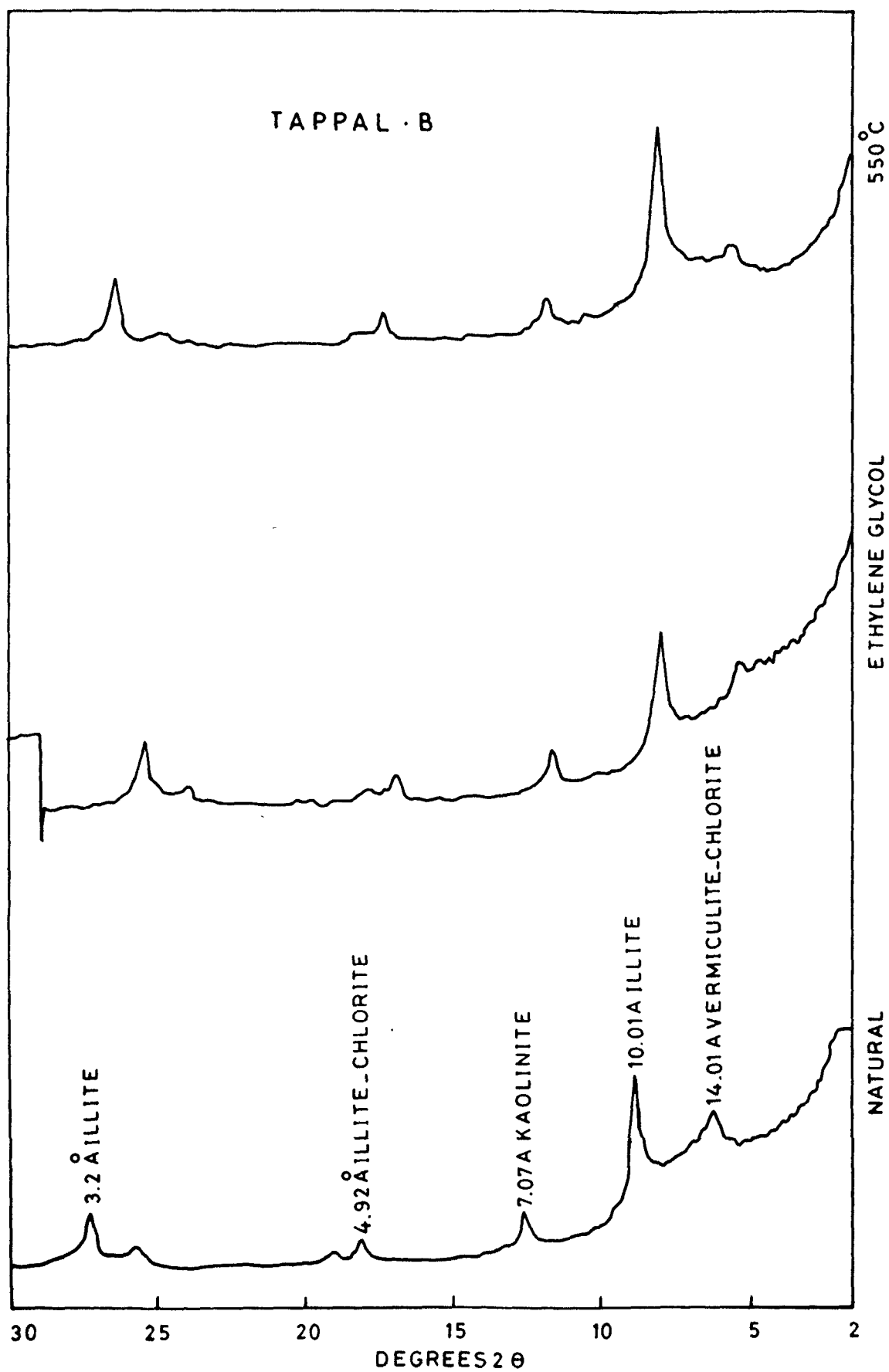


FIG. 24-ORIENTED X-RAY DIFFRACTOGRAM

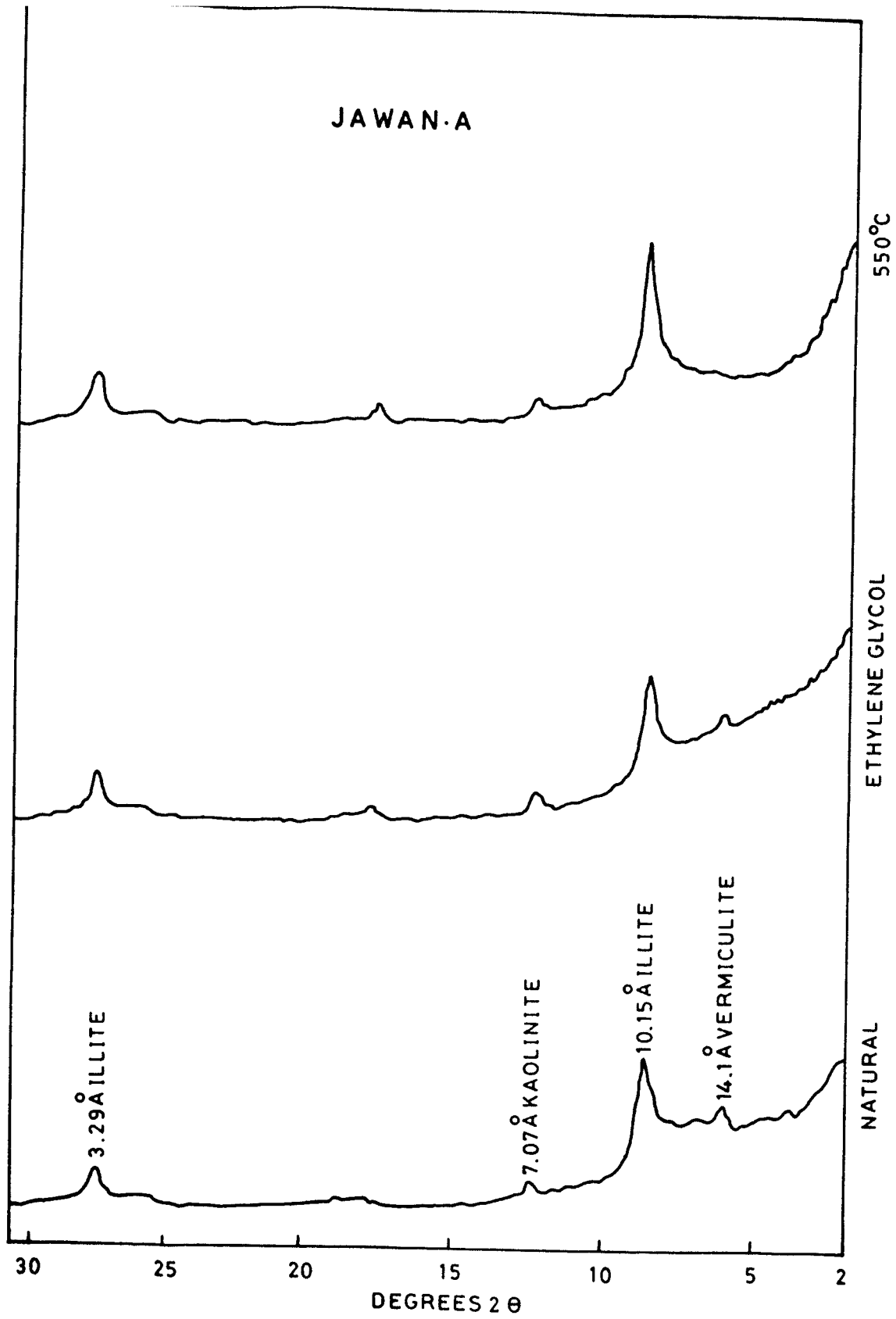


FIG-25-ORIENTED X-RAY DIFFRACTOGRAM

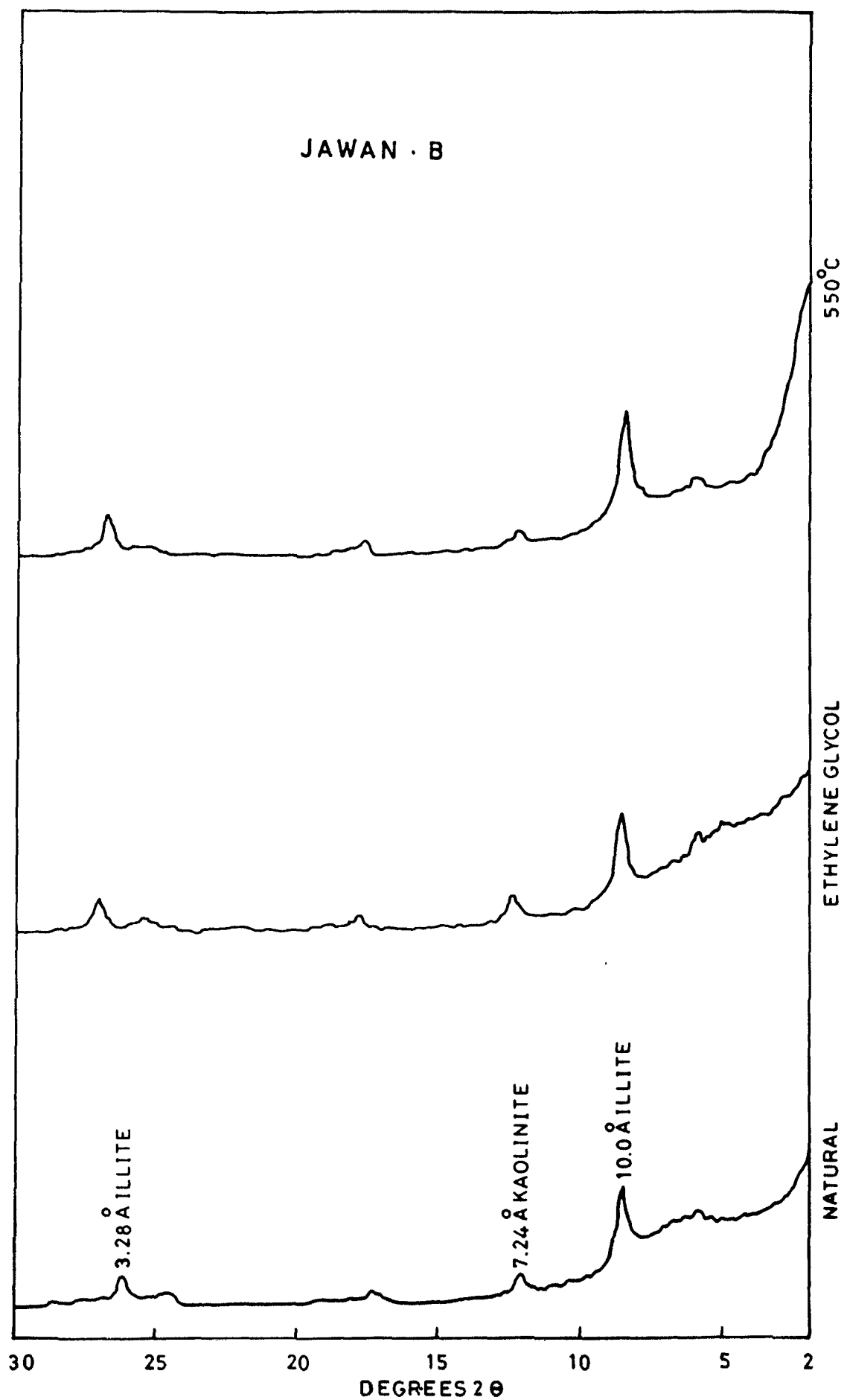


FIG. 25 — ORIENTED X-RAY DIFFRACTOGRAM



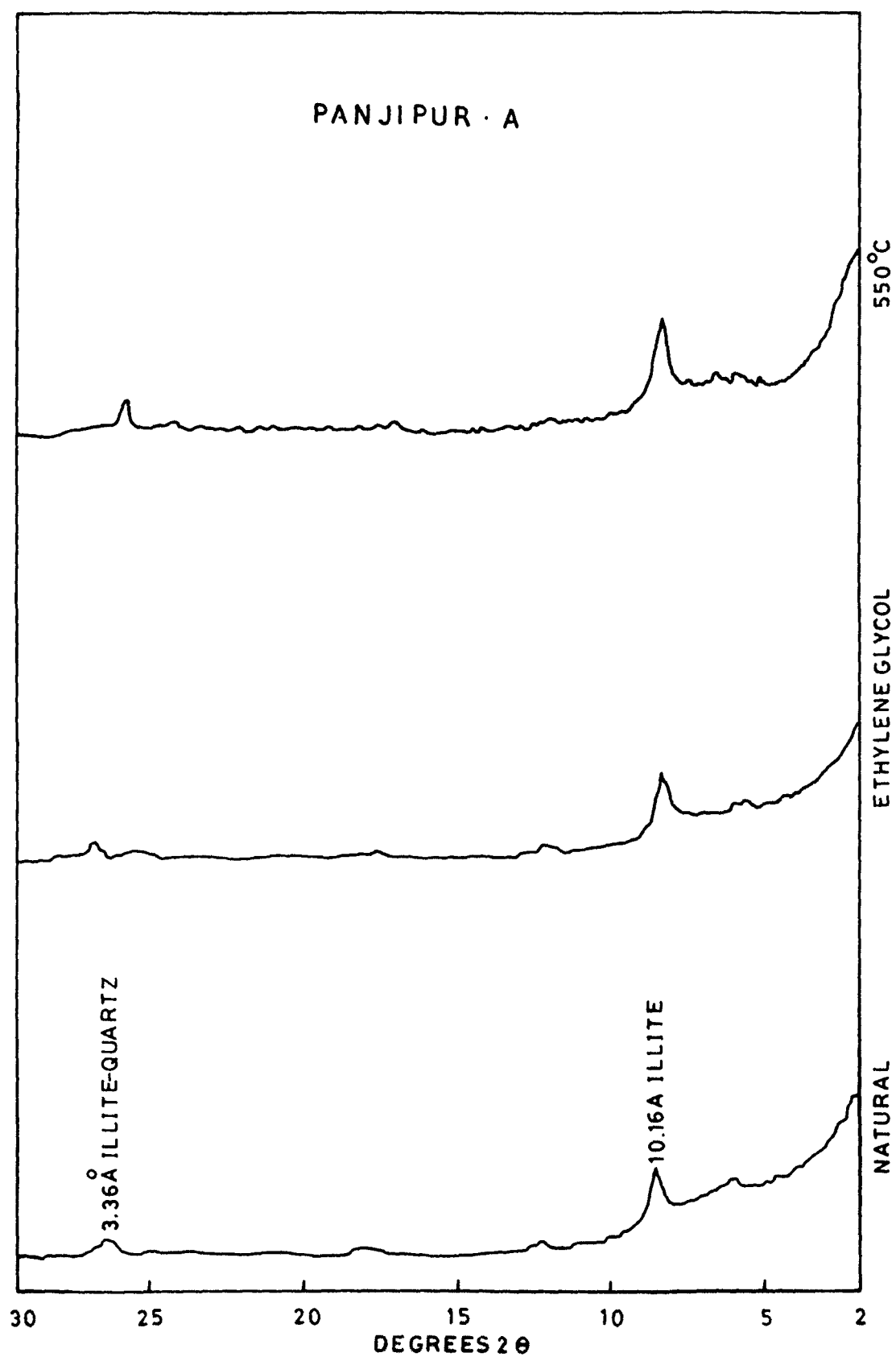


FIG · 26 - ORIENTED X-RAY DIFFRACTION TOGRAM

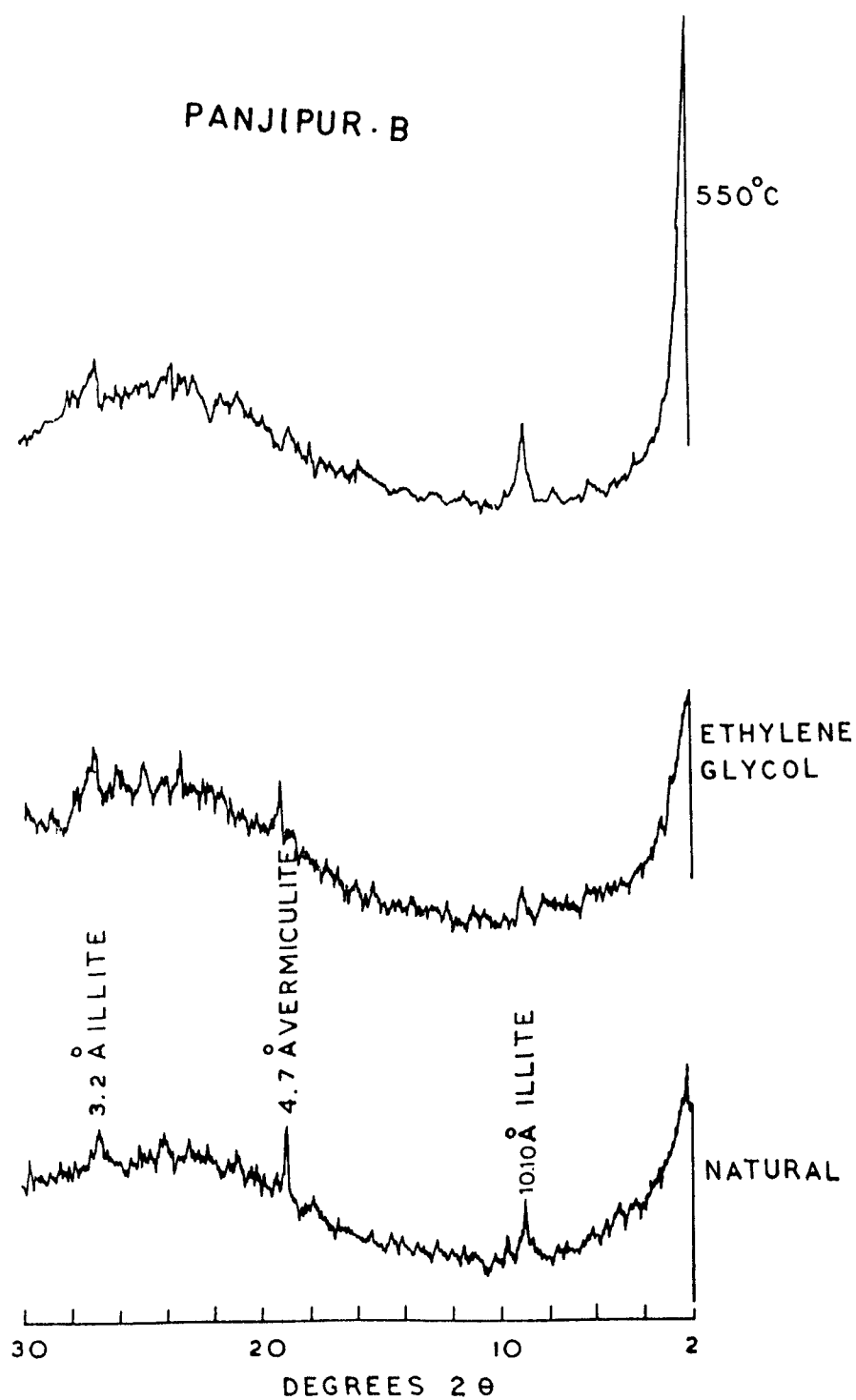


FIG-26-ORIENTED X-RAY DIFFRACTOGRAM

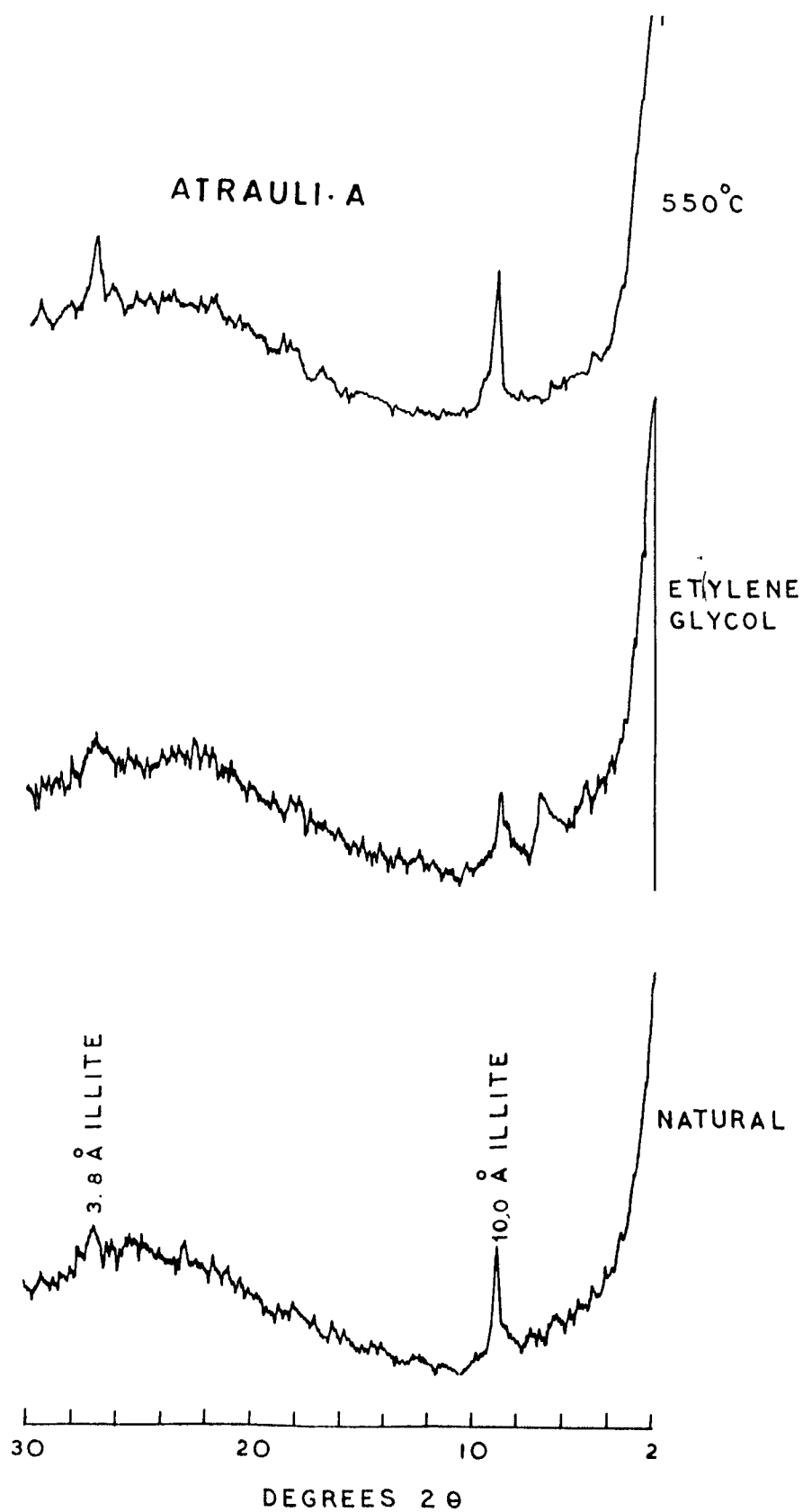


FIG-27-ORIENTED X-RAY DIFFRACTOGRAM

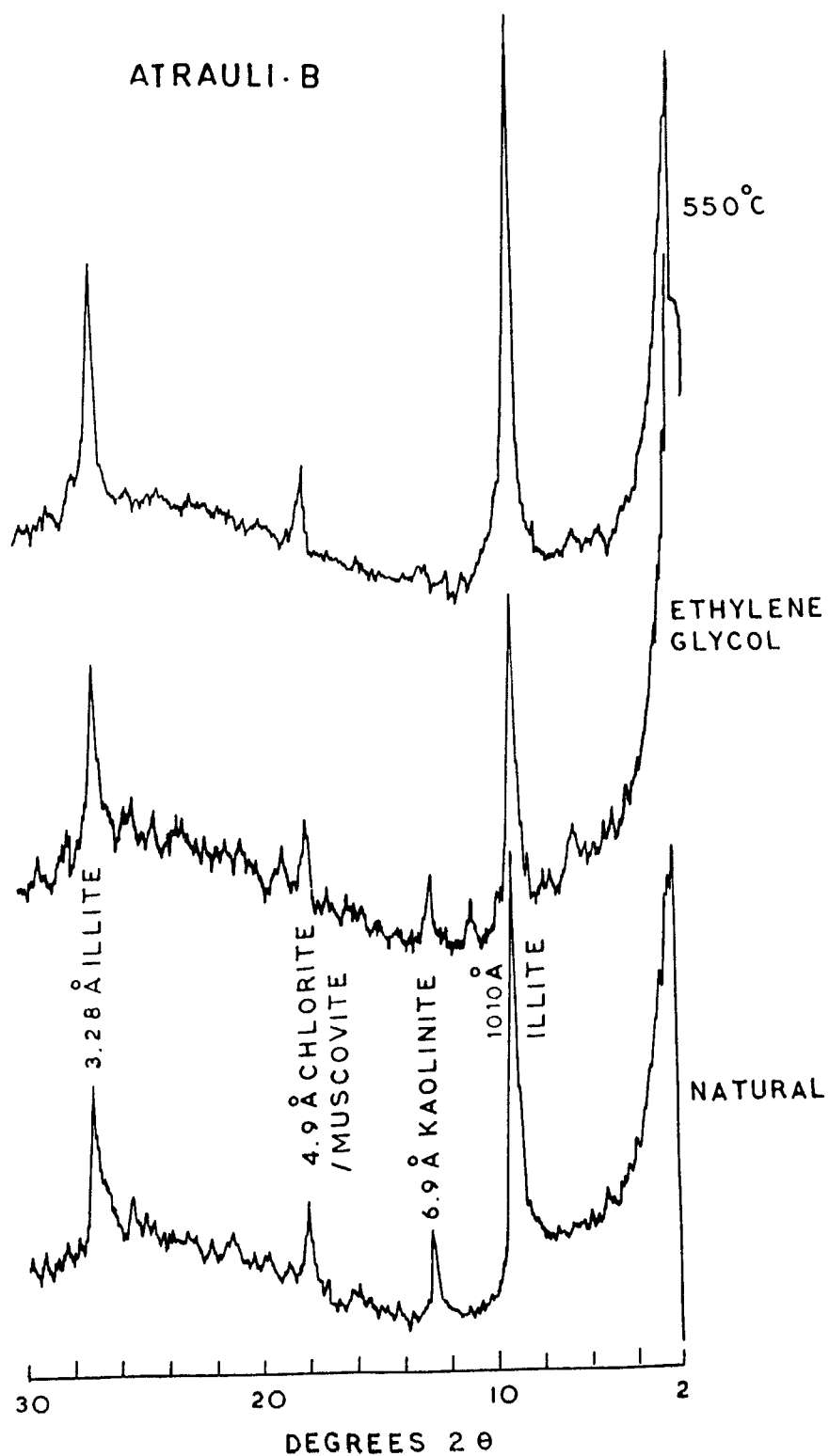


FIG-27-ORIENTED X-RAY DIFFRACTOGRAM

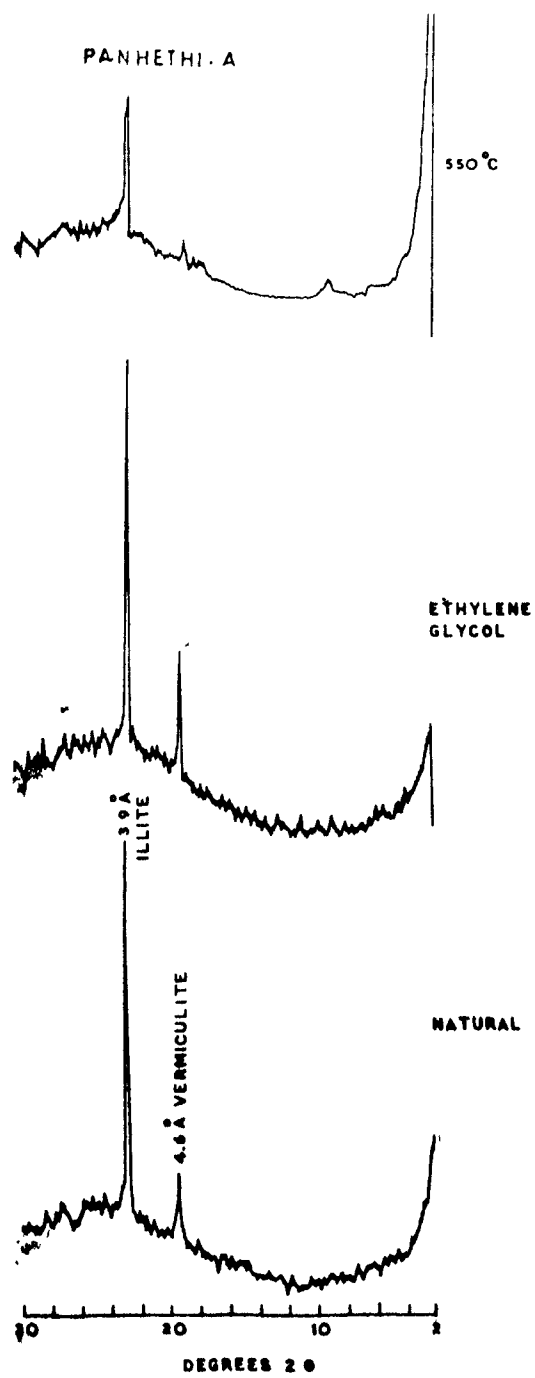


FIG-28-ORIENTED X-RAY DIFFRACTOGRAM

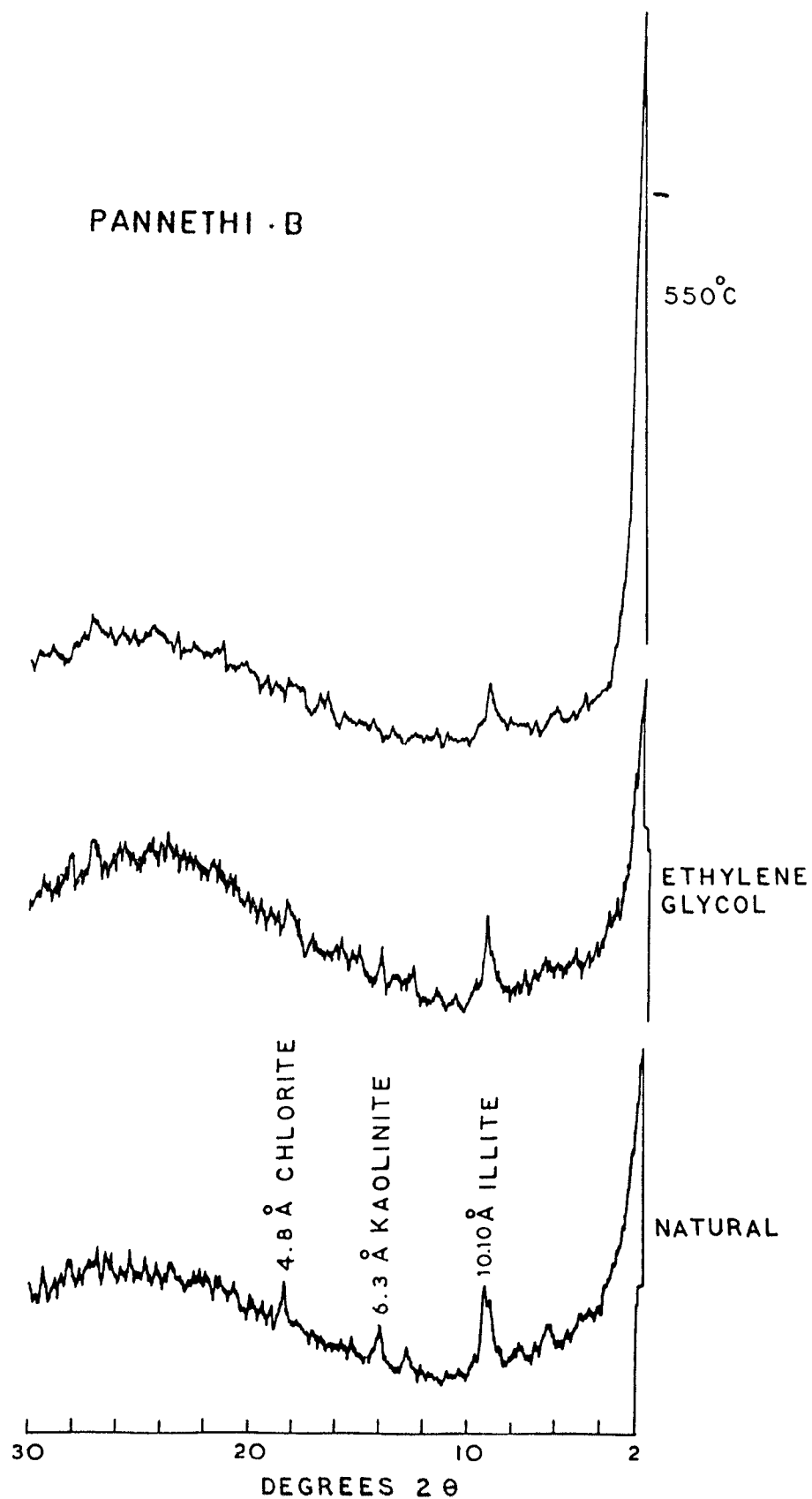


FIG-28-ORIENTED X-RAY DIFFRAC OGRAM

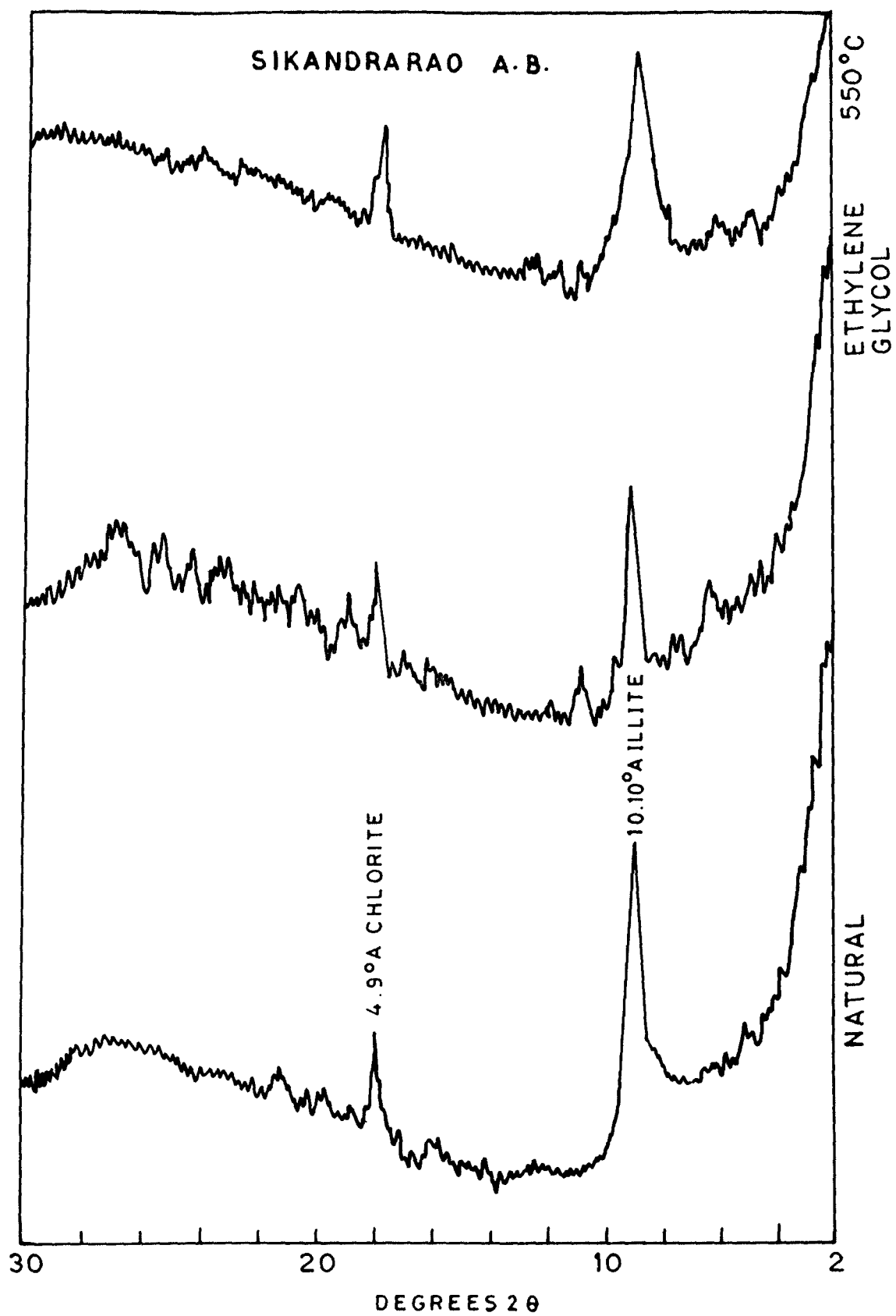


FIG. 29

main clay minerals in the 'Reh' soils of Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao (Figs. 24 AB, 25 AB, 26 AB, 27 AB, 28 AB, 29 AB).

The characteristics of various minerals are given as follows :-

#### Illite

This group is characterised by strong peaks at  $10 \text{ \AA}$  and  $3.3 \text{ \AA}$  on the diffractogram of natural, glycolated and heated samples. The dioctahedral illite has a peak at  $4.98 \text{ \AA}$ . The  $10 \text{ \AA}$  peak is somewhat asymmetrical with a tail extending towards low angles. Such illites common in India soils, have been termed as 'degrading illite' by Brown (1954). Such degraded illites were, subsequently, found as mixed layer minerals. The K-saturation often removes the asymmetry to give a relatively strong peak (Pl. 5).

#### Chlorite

This group gives a series of prominent basal reflections at approximately  $14$ ,  $7$ ,  $4.7$  and  $3.6 \text{ \AA}$  which persist even when heated. However, identification of chlorites pose problem in the presence of minerals with  $7 \text{ \AA}$  peaks, like kaolinite.



PLATE 3

Scanning electron micrograph showing Card-house structure formed by crystals of illite in the soil sample of Aligarh area.



PLATE 5

### Vermiculite

Vermiculite treated with glycol gave strong 14 Å peak. This mineral is characterized by its dehydration behaviour. On heating, the 14 Å reflection collapses to 10 Å.

### Mica

The presence of a little amount of mica, in degraded form, is evident from a small and broad peak at 10 Å with its sub-multiples at approximately 5 Å and 3.3 Å.

### Kaolinite

The minerals of this group gave strong reflection at 7 Å which disappears on heating due to the destruction of structure. Thus, diffractogram of heated sample is diagnostic in distinguishing kaolinite from true chlorite.

In 'Reh' soils illite is the main clay mineral associated with chlorite/vermiculite and kaolinite. The soils of eastern U.P. abound in illite and montmorillonite along with a significant amount of chlorite (Gupta, 1961). The soils of central and western U.P., however, have illite and chlorite as the main clay minerals (Gupta, 1968; Khan and Singhal, 1968; Chatterjee and Gupta, 1970; Jadav and Gupta, 1972).

The alluvial soils of Delhi, Punjab and Haryana are dominantly illitic along with one or more of the minerals like kaolinite, chlorite, mixed layer mineral and montmorillonite (Dass, 1956; Singh, 1972). The saline alkaline soils have illite and kaolinite (Raychowdhury, 1953), illite and chlorite (Kanwar, 1961; Pandey and Pathak, 1972) illite and montmorillonite (Patel, 1969).

The saline alkaline soils of Aligarh have illite as the dominant clay mineral in association with chlorite, vermiculite, kaolinite alongwith quartz, feldspar and a little mica (Table-23) Chlorite and vermiculite occur as interstratified minerals at all places.

There is absence of kaolinite at Panhethi (top horizon), Atrauli (Lower horizon), Panjipur and Sikandra Rao (both top and lower horizons) but dominance of feldspar (Table-18).

#### 6.7. THIN SECTION STUDIES

The arrangement and relationships between minerals in soil is more complex than that found in rocks. The plasmic fabrics of soil minerals, structure of microsparites, sparites, and kankar nodules, effect of clay minerals on other precipitates and organic and inorganic accumulations are some of the features which can be studied in the thin sections. Micromorphological studies of thin sections of the soils of Aligarh

were carried out. They have sandy loam to clay texture and secondary growth of calcite. The results are presented and discussed in the proceeding discussion.

#### 6.7.1. Micromorphology of Soils

Few mineralogists have attempted soil micromorphological studies on the Indian soils that too on a smaller scale. The importance of micromorphological studies of soils has already been emphasized in the understanding of environmental conditions, primarily in the tropics and subtropics. In micromorphological study of soils at Aligarh, several features were observed.

Calcite crystals of three size grades were recognised. They are microcalcite, microsparites and sparites. Microcalcite is an equivalent of micrite of sedimentary rocks. The use of the term microcalcite is preferable to micrite in order to differentiate between the two.

The microsparite are recognisable small crystals between 8-20  $\mu$ m in size. They are distributed non-uniformly in the non-carbonate clay and are associated with recrystallization processes.

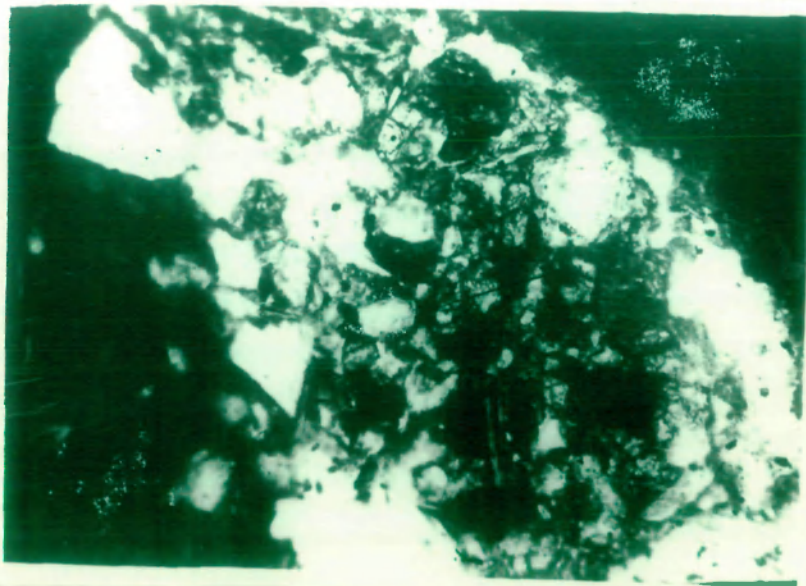
The sparites represent large crystals, greater than 20  $\mu$ m of high purity, lacking in inclusions of clay minerals. Microsparites and sparites constitute crystic fabrics resulting from the direct precipitation and recrystallisation.

PLATE 6

- a        Thin section of Reh soil from Aligarh showing micro-calcite (micrite), inter-mixed with clays (+ nicol x 50).
  
- b        Thin section of soil from Panjipur showing aggregate of rhombohedral calcite crystals along a passage developed in sandy soil. (+ nicol x 50).



(a)



(b)

PLATE · 6



Calcite is an unstable phase under humid conditions but is stable under arid and semi-arid conditions. In the regions of reh, a calcic (or calcon) horizon occurs at about 30 cm below the surface. The carbonates are, generally, intermixed with clays and form microcalcites. Local accumulation of clay cutans in voids of soil material gives rise to calciasepic fabric. As a rule the greater the amount of clay content in calciasepic fabric the smaller are the grain size of microcalcites and vice versa (Pl. 6 a).

Under certain microenvironmental conditions these locations will be the sites of precipitation of calcons. In the sandy textured soils, secondary carbonates precipitate as large sparry crystals with clear rhombohedral faces. A definite relationship exists between the silt fraction and total carbonates to the size of calcite crystals. (Pl. 6, Fig. b and Pl. 7, Fig. a)

The presence of biota of both plants and animals directly influence the carbonate forms. Two kinds of biogenic effects can be detected in the soils of Aligarh.

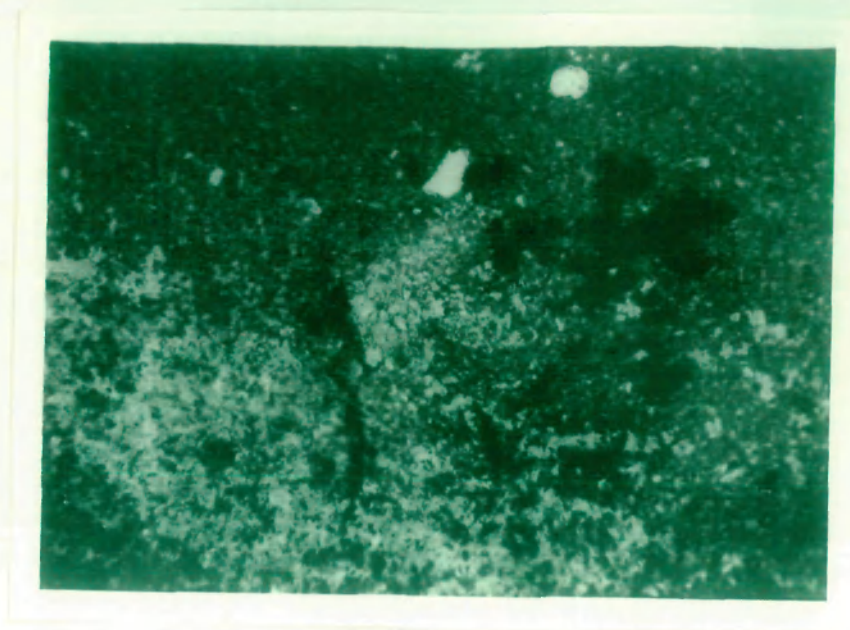
- (1) bioturbation of existing forms
- (2) direct influence on the environment of precipitation.

Bioturbation is frequently, due to activities of earthworms and similar other organisms such as, termites and beetle larvae. The burrow through the soils and create passages (channels) as observed at Tappal area.(Pl. 7 b)

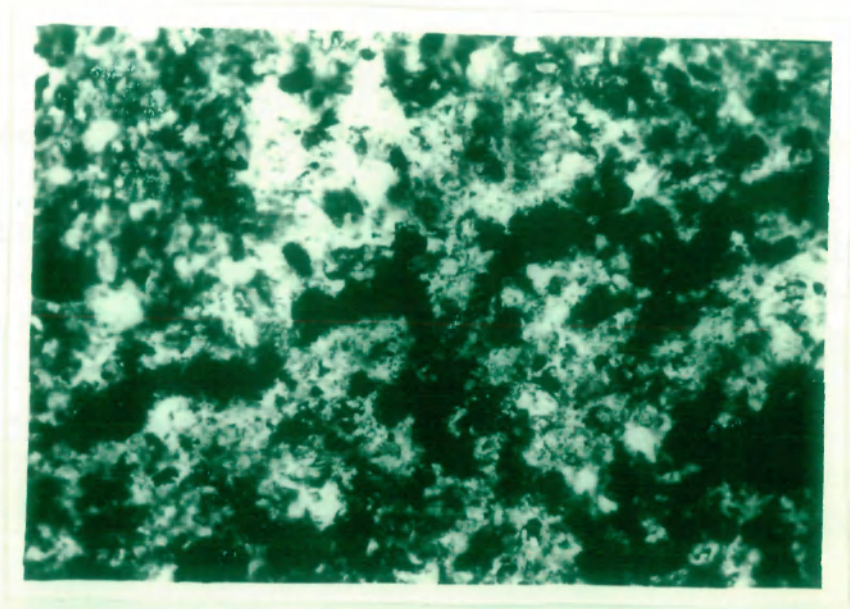


PLATE 7

- a      Thin section of soil showing textural relationship between silt fraction and carbonates (calcite) (+ nicols x 25).
  
- b      Thin section of soil photograph shows filled burrow channels (Bioturbation) of earthworms (black) (+ nicol x 25).



(a)



(b)

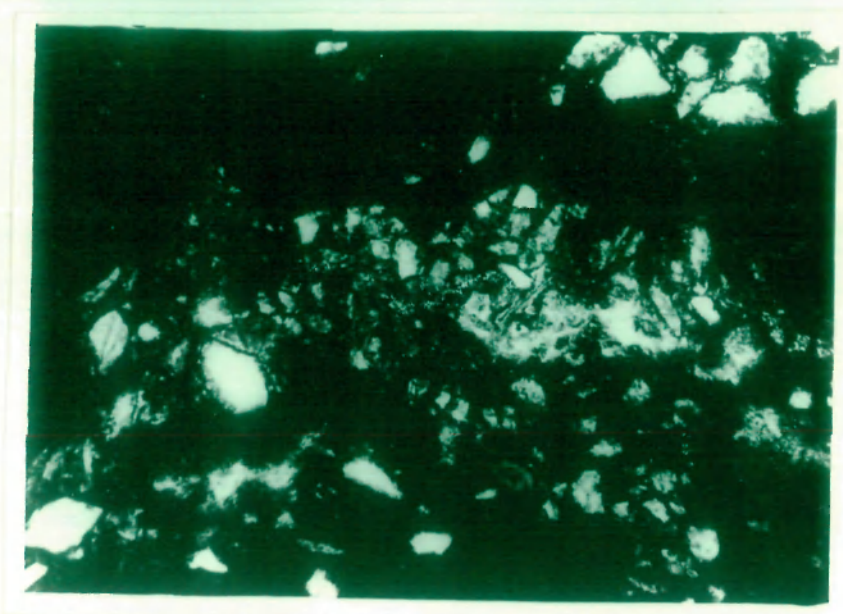
PLATE 7

The influence of organism on carbonate precipitation can be observed around the plant roots. The metabolism of roots creates a new environment locally and causes growth of dense micrite around it. One effect is the increase of  $\text{CO}_2$ -pressure due to release of  $\text{CO}_2$  gas from the dessicating soil solution. Confirmation of this is found in many semi-arid and arid areas (Fitzparick, 1984). The type of calcium carbonate accumulation varies from soil to soil in the form of pseudomycelium to large rhombohedral crystals.

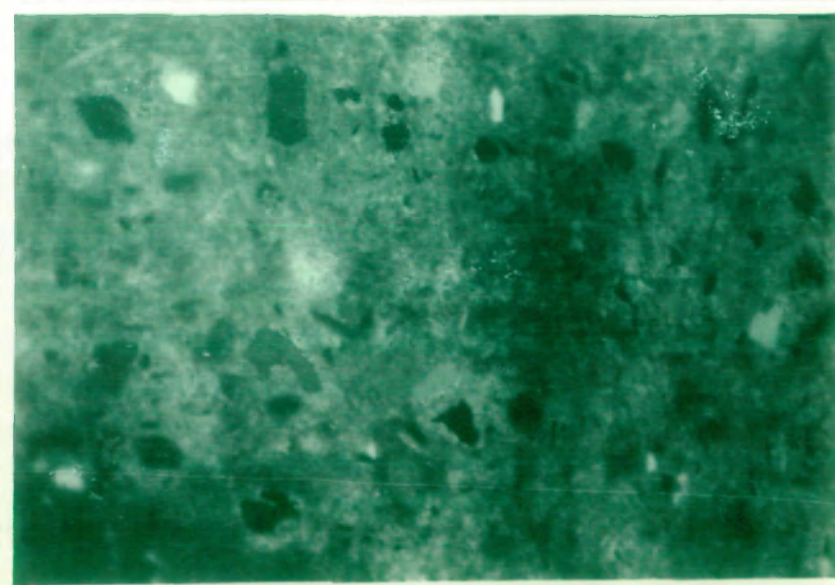
At Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao, sand soils contain rhombohedral crystals of calcite. The crystal vary in size due to such factors as pH, concentration of calcium bicarbonate, rate of crystallization and closeness of water table to the surface. The Indo-Gangetic alluvium contains high  $\text{CO}_3$  and  $\text{HCO}_3$  and, therefore, large zones of calcite 'kankar' seems to be due to specific chemical situations in these zones which favour growth of large calcite crystals (Pl.6, Fig.b, Pl.8, Fig.a). This is aided by capillary action during the dry seasons. The growth of larger crystals force away the soils so that small islands of original soil become completely surrounded by secondary calcite. As a result groundmass minerals like quartz, feldspars and heavy minerals appear surrounded by micrite crystals in the thin sections.

PLATE 8

- a      Thin section of soil photograph showing growth of large  
         crystals of calcite indicating capillary action.  
         (+ nicol x 15).
  
- b      Thin section of Reh soil concretion showing distribution of  
         carbonate and other minerals in a fine grained matrix.  
         (+ nicol x 15).



(a)



(b)

PLATE · 8

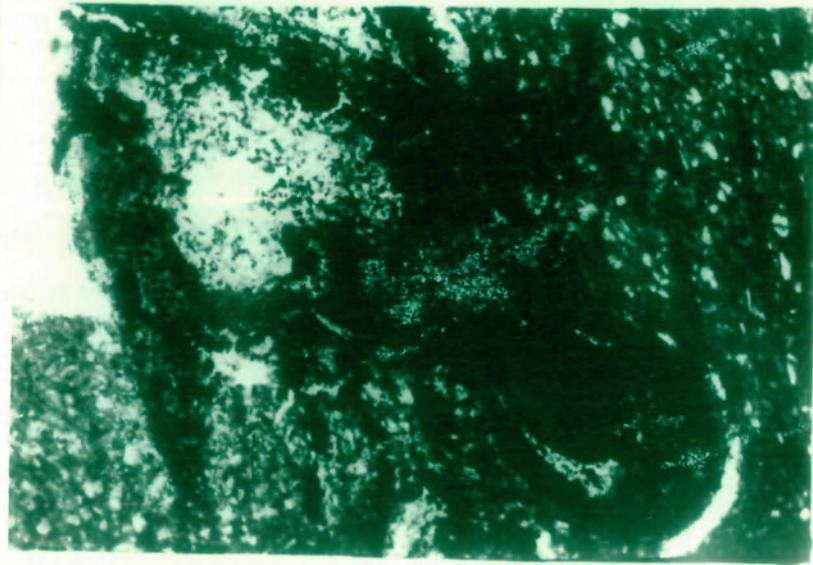
Concretions : In this section kankars are composed of inequigranular crystals. The matrix is fine-grained clayey-loam. The calcareous mass appears colourless, resembling divitrified glass (Brewer, 1964; Parafenova and Yarilova, 1964; Roonwal, 1975; Awasthi and Chopra, 1981). The cryptocrystalline carbonate matrix forms concentric rims or occurs as plain mass. There is often a quartz nucleus around which calcite is deposited producing an illusion of a volcanic rocks showing hyalophitic texture. The matrix is composed of grains of calcite, dolomite, some gypsum (?) needles and often, biotite needles loosely scattered indicating flow. Presence of hydrated ironoxide in the matrix indicates authogenic secondary origin of kankar as 'white eye' (beloglazka). (Pl. 8, Fig. b).

Apart from calcareous concretions some rounded ferruginous concretions of dark reddish brown colour are also found. The concretions have compact and annular structure with clays. Each layer represents a soil microarea differing from others in the amounts of free iron oxide. The occurrence of iron balls is not uncommon in soils and clays. The finely disseminated hydrous iron oxide imparts various shades of yellow, red and brown colour to the soils. In Aligarh, the soils at upper parts hematite and limonite are present. The oval shaped iron balls may be joined by a common ferruginous layer outside and linings inside. ( Plate - 10, Fig. b) Such amorphous iron oxide formation has been reported from various other places (Wada and

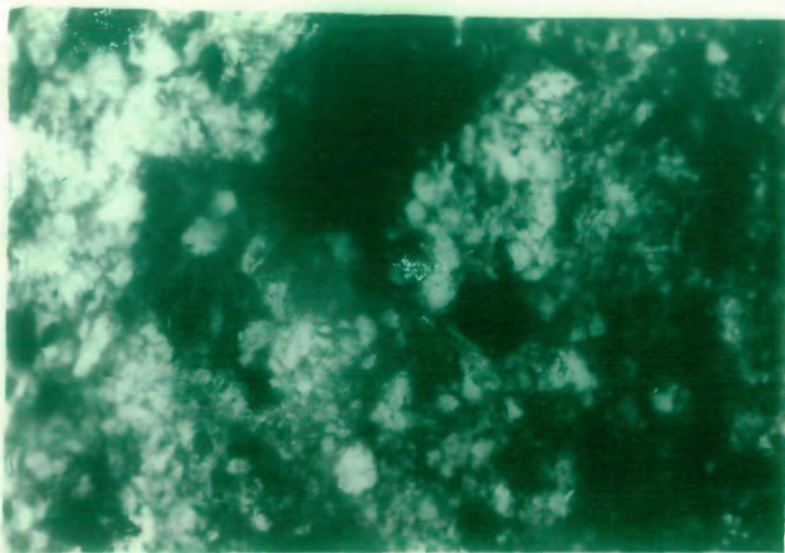


PLATE 10

- a      Thin section of Reh soil showing oval shape iron concretion. Note coating of calcite crystals mixed with quartz grains around it.
  
- b      Concretions of iron showing core of crystal of calcite mixed with quartz and clay.



(a)



(b)

PLATE 10

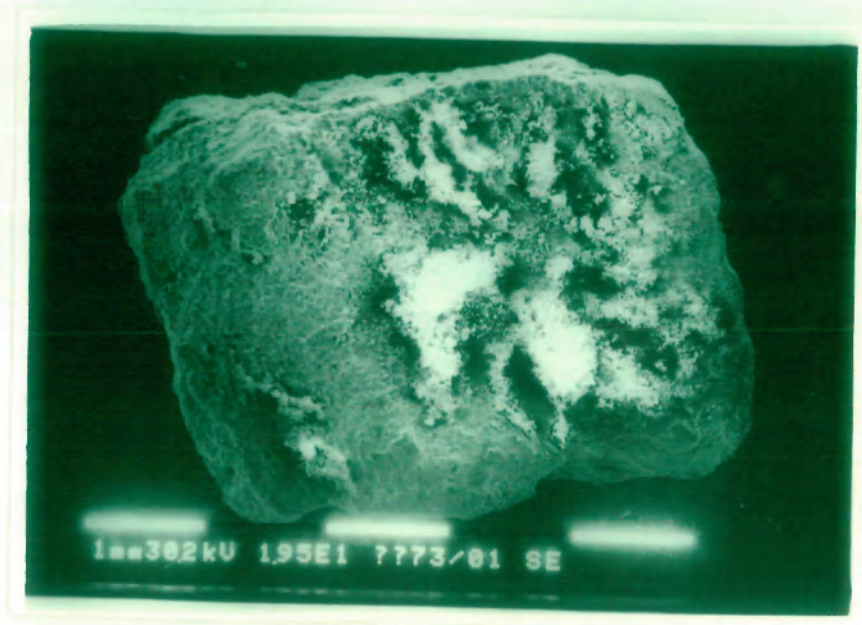


Matsubara, 1968; Gorbunov, 1968; Deconink, 1968; Eswaran, 1971; Agarwal, 1971; Igue and Fuentes, 1972; Murthy, 1982; Sharma and Yadav, 1986). Thus it is clear from the studies that active Fe is generally higher in the surface soils and decreases with depth. The alkaline conditions bring about degradation of minerals, leaching to accumulation of Si, Al and Fe. The highly sodic conditions of soils would favour degradation of minerals and removal of iron from octahedral sites of the silicates. Moreover, weathering is also more intense at the surface. But the released excess iron at the surface fails to leach to the lower layers of soils due to poor permeability under alkaline conditions.

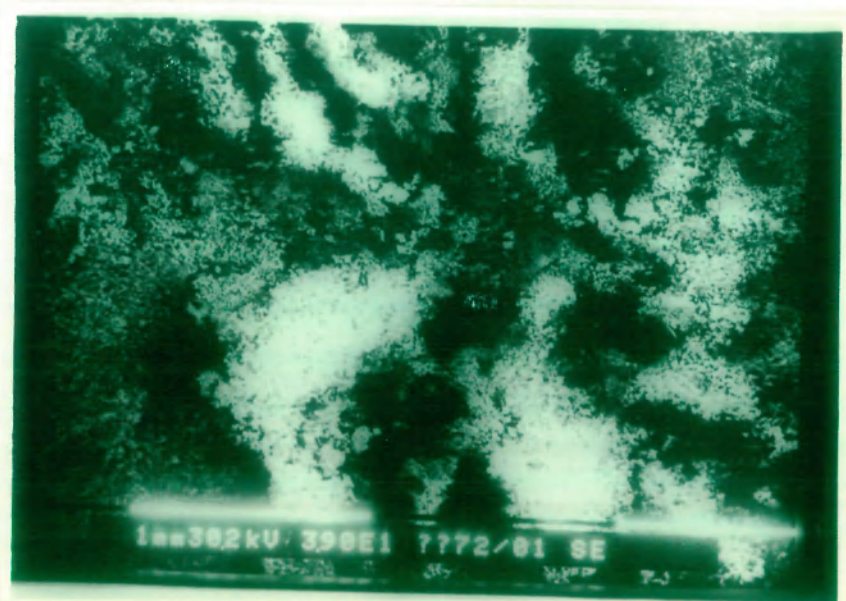
On the contrary, in low lying, water-logged areas (central lowlands), Fe is concentrated in lower horizons, closer to groundwater-table. The intense reducing condition prevail at deeper levels as observed at Jawan, Panhethi, Panjipur and Sikandra Rao, thereby converting Fe to its more soluble form. This appears to be the cause for higher concentration of reducible iron in the deeper layers (Turner and Patrick, 1968). An interesting specimen of soils shows oval and rounded iron structure with iron nucleus surrounded by calcite layer. It was filled inside with small crystals of calcite, quartz and micas (Figure - a). The nodule might have formed either due to transportation and redeposition or due to in situ leaching of limonite.

PLATE 9

a & b   Scanning electron micrograph of soil samples  
          showing radiating white salt crystals due to  
          efflorescence and capillary action.



(a)



(b)

PLATE 9

In Aligarh, the soils display distinct salt crusts mainly of carbonates and bicarbonates. This efflorescence is related to capillary action. The study reveals the following :-

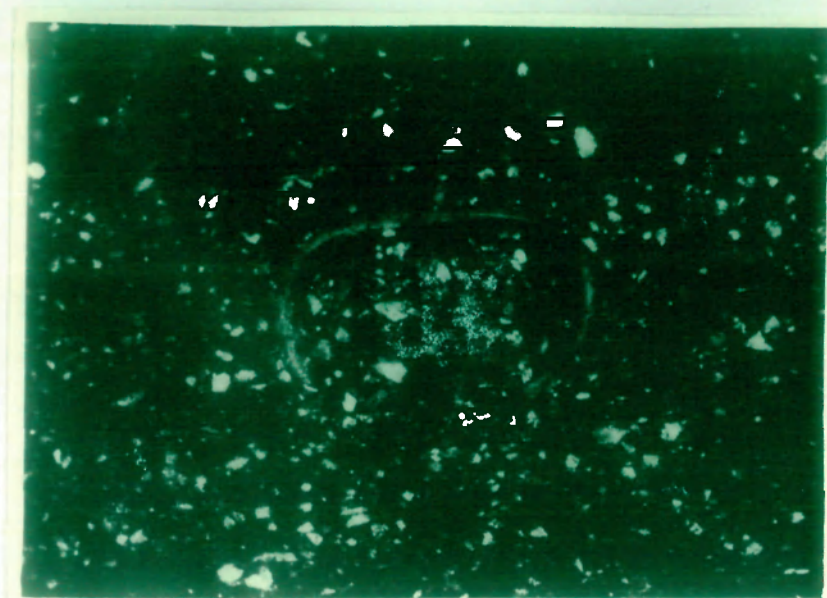
1. Efflorescence on the pore walls occurs due to evaporation. The soil solution moves from the interpore space (plasma) toward the air filled pore, precipitating salts on its walls. (Pl. 9, Fig. a; Pl. 9, Fig. b).
2. Efflorescence within the plasma occurs when the concentration of solution is so high that the salts are precipitated before the solution reaches the pore.
3. Salts are deposited on the pore walls either chemically or mechanically.

Thus it can be concluded that calcium moves in a dissolved state as bicarbonate along the soil profiles of Aligarh district. A concentrated solution, with its alkaline reaction and comparatively high evaporation rate produces efflorescence in the form of calcite crystals.

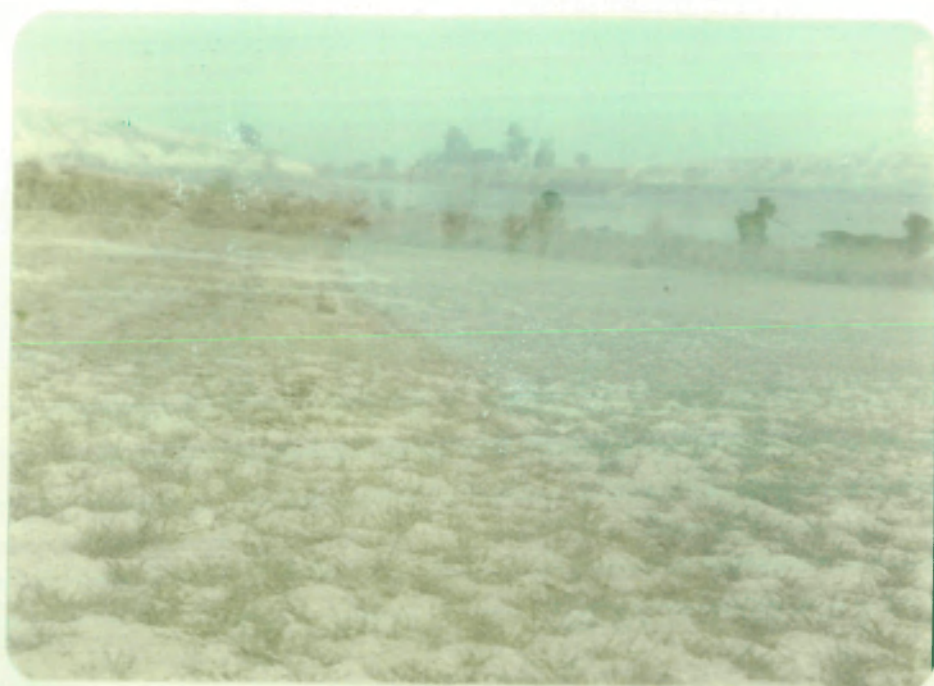
In one thin section (Plate-11, Fig. a) a recrystallized bivalve shell is seen. Its upper part is well preserved but lower portion shows only its remnant. This possibly seems to be a recent shell which, during dry season got embeded in the soils.

PLATE 11

- a        A thin section of Reh soil showing a bivalve shell in cross section. (+ nicol x 25).
  
- b        Photograph showing a field adjacent to upper Ganga canal (in the background). Note extensive encrustations of Reh on the surface of soil.



(a)



(b)

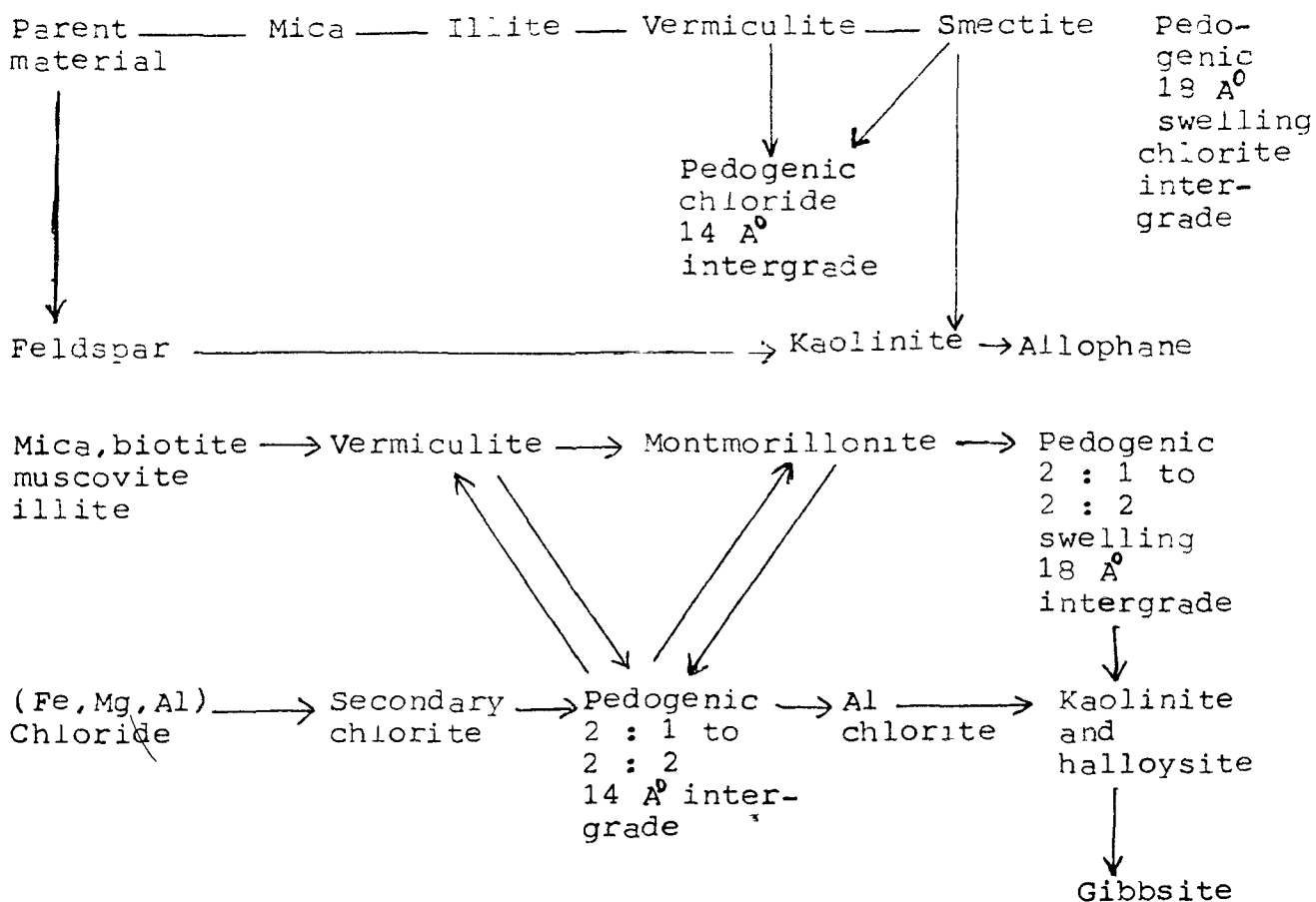
PLATE 11

#### 6.8. GENESIS OF CLAYS IN ALIGARH SOILS

Hydrous micas, represented by illites are considered as alteration product of micas. Illite can, however, recrystallise from the minerals, such as the potash feldspars, with abundant supply of potassium. The study indicates that illite, vermiculite, chlorite and kaolinite are products of weathering. Vermiculite too is a weathered product of micas. They can be accounted for by geomorphic processes under restricted drainage and high alkalinity conditions (Jackson, 1965). Chlorites can be derived from vermiculite through reactions in which positively charged brucite layer might replace the interlayer water and hydrated cations (chloritization). Such replacements, when incomplete, result in a phase transitional towards chlorite.

Most feldspars in the soils of Aligarh are highly weathered. Partial hydrolytic decomposition of feldspar under alkaline conditions has been invoked to explain the presence of kaolinite (Koller, 1962; Kaswala and Deshpande, 1983), in these soils. It is most likely that they were inherited from the parent rocks from Himalayas as the calcareous soils are known to block kaolinization. A model for the formation of minerals in the Reh soils of Aligarh can be given as follows :-





But in situ pedogenesis favourable for the formation of a saline-alkali soils will favour the formation of clay minerals. Scarcity of feldspars and mica at deeper levels will be effected due to the pedogenic process.



## CHAPTER - VII

## GEOCHEMISTRY OF 'REH' SOILS OF ALIGARH AND THE SURROUNDING AREAS

There are two broad classes of materials which make up the solid phases of soil minerals and organic matter. As in most cases, bulk of the soils of Aligarh consists of oxides of silicon, aluminium and iron.

7.1. pH AND ELECTRICAL CONDUCTIVITY

The pH and E.C. of the soils were determined and are presented in Table-20.

The pH of these soils vary from 9.8 to 10.95 at Tappal, 8 to 8.5 at Jawan, 8.8 to 10.9 at Panjipur, 9.3 to 9.8 at Atrauli, 8.9 to 9.8 at Panhethi and 8 to 8.9 at Sikandra Rao. The E.C. of the various soil horizons range from 0.80 to 3.89 mmhos/cm in Tappal, 8.20 to 14.60 mmhos/cm in Jawan, 0.14 to 0.43 mmhos/cm in Panjipur, 9.3 to 10.5 mmhos/cm in Atrauli, 0.25 to 3.40 mmhos/cm in Panhethi, 4.31 to 14.12 mmhos/cm in Sikandra Rao.

The exchangeable cations, C.E.C., in these soil vary from 2.90 to 3.39 meq/100 gm in Tappal, 1.55 to 4.49 meq/100 gm in Jawan, 2.04 to 3.67 meq/100 gm in Panjipur, 2.00 to 5.31 meq/100 gm in Atrauli, 2.03 to 4.14 meq/100 gm in Panhethi and

Table-20 : Chemical characteristics of Reh soils of Aligarh District (U.P.).

Depth (cm)	pH 1:2 fl water	EC (mmho./ cm)	Exchangeable Cations				Cation Exchange Capacity
			Ca <sup>++</sup>	Mg <sup>++</sup>	Na <sup>+</sup>	K <sup>+</sup>	
			(meq/100 gm soil)				
<u>Faigal</u>							
0.0-48.1	10.95	3.89	3.39	1.85	8.93	0.48	14.65
48.1-60.5	10.20	1.26	2.90	1.30	9.10	2.60	15.90
60.5-70.3	9.83	0.33	2.91	1.91	8.87	1.10	14.79
90.3-125.3	10.61	1.41	3.10	1.48	10.13	1.38	19.50
125.3-130.1	9.33	0.80	3.39	2.60	12.10	2.00	20.09
<u>Jawan</u>							
0-30	3.30	14.10	2.68	0.43	9.20	0.46	12.77
30-70	3.10	11.10	4.49	2.40	8.69	0.30	13.88
0-94.1	3.50	8.20	4.06	2.01	12.15	0.31	17.53
94.1-110	3.30	14.60	2.96	0.45	9.19	0.32	12.92
110-129	8.00	13.40	1.55	0.49	8.10	0.38	10.43
<u>Faujfar</u>							
0-5	10.97	0.15	2.15	1.08	8.50	0.43	12.16
5-86	9.12	0.17	2.97	2.12	6.14	0.32	11.55
86-135	9.20	0.13	3.67	1.90	4.13	0.19	9.89
135-145	9.80	0.43	2.81	1.30	4.07	0.39	9.67
145	3.90	0.14	2.04	1.69	4.83	0.59	9.15
<u>Chandoli</u>							
0-25	9.70	1.19	2.00	0.96	11.59	0.93	15.48
25-71.3	10.50	0.31	5.10	1.85	12.01	1.33	20.29
71.3-45.2	9.30	0.93	5.31	1.20	26.05	1.29	33.85
45.2-57.0	9.30	1.25	2.10	1.19	31.14	1.08	35.51
57.0-105	9.80	1.02	3.88	1.93	12.39	1.98	20.18
<u>Panhatli</u>							
0-10.3	9.90	0.55	2.11	1.00	8.06	1.31	12.48
10.3-51.2	9.80	1.05	2.03	1.51	8.91	1.06	13.51
51.2-80.9	9.30	0.51	4.14	1.10	10.35	1.35	16.94
80.9-121.3	9.30	0.49	3.01	1.83	12.43	1.21	18.48
121.3	9.60	3.40	3.85	1.31	8.11	1.11	14.38
<u>Sikandi Rao</u>							
0-20.0	9.30	6.50	5.01	4.00	7.10	0.22	17.33
20.0-41.8	3.50	4.31	5.84	3.86	8.00	0.42	18.12
41.8-65.3	8.00	11.01	2.34	3.34	8.71	0.39	14.78
65.3-83.0	8.90	11.13	2.48	2.23	7.90	0.32	12.93
83.0-121.8	8.50	14.12	3.65	2.17	7.10	0.27	13.19

2.34 to 5.84 meq/100 gm in Sikandra Rao (Table-20).

The exchangeable magnesium remains more or less uniform. Its amount vary from 1.30 to 2.60 meq/100 gm in Tappal, 0.43 to 2.40 meq/100 gm in Jawan, 1.08 to 2.12 meq/100 gm in Panjipur, 0.96 to 1.93 meq/100 gm in Atrauli, 1.00 to 1.83 meq/100 gm in Panhethi and 2.17 to 4.00 meq/100 gm in Sikandra Rao.

The exchangeable sodium is dominant in these soils and vary from 8.87 to 12.10 meq/100 gm in Tappal, 8.10 to 12.15 meq/100 gm in Jawan, 4.07 to 8.50 meq/100 gm in Panjipur, 11.59 to 31.14 meq/100 gm in Atrauli, 8.06 to 12.43 meq/100 gm in Panhethi and 7.10 to 8.71 meq/100 gm in Sikandra Rao.

The exchangeable potassium, was found more or less constant vertically in these soils. The values vary from 0.48 to 2.60 meq/100 gm in Tappal, 0.30 to 0.46 meq/100 gm in Jawan, 0.19 to 0.59 meq/100 gm in Panjipur, 0.93 to 1.98 meq/100 gm in Atrauli, 1.06 to 1.35 meq/100 gm in Panhethi and 0.22 to 0.47 meq/100 gm in Sikandra Rao.

The cation exchange capacity is generally high in all types of soils. It varies from 14.65 to 19.5 meq/100 gm in Tappal, 10.43 to 17.53 meq/100 gm in Jawan, 8.67 to 12.16 meq/100 gm in Panjipur, 15.48 to 35.51 meq/100 gm in Atrauli, 12.48 to 18.48 meq/100 gm in Panhethi and 12.93 to 18.12 meq/100 gm in Sikandra Rao.

### 7.1.1. Saturation Extract Analysis (Table-21)

#### Soluble Cations

No clear pattern could be established for soluble calcium in the soils of Aligarh and surrounding areas. The values vary from 1.30 to 2.58 meq/lit in Tappal, 1.50 to 14.41 meq/lit in Jawan, 1.31 to 1.86 meq/lit, 1.90 to 3.20 meq/lit, 1.00 to 2.00 meq/lit and 0.98 to 9.10 meq/lit in Panjipur, Atrauli, Panhethi and Sikandra Rao, respectively. The soluble magnesium is less than soluble calcium varying from 0.33 to 1.05 meq/lit, 0.97 to 20.10 meq/lit, 0.19 to 0.90 meq/lit, 0.10 to 1.80 meq/lit, 0.58 to 1.21 meq/lit and 0.50 to 4.30 meq/lit in Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao, respectively.

Like calcium and magnesium, sodium have high distribution values. It varies from 130.15 to 154.31 meq/lit, 25.14 to 96.5 meq/lit, 90.10 to 148.10 meq/lit, 25.46 to 34.38 meq/lit, 112.30 to 145.90 meq/lit and 0.19 to 41.89 meq/lit in Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao areas, respectively. The soluble potassium is low and varies from 0.08 to 2.30 meq/lit, 0.20 to 1.20 meq/lit, 0.04 to 0.51 meq/lit, 0.01 to 0.30 meq/lit, 0.01 to 0.40 meq/lit and 0.10 to 1.39 meq/lit in Tappal, Jawan Panjipur, Atrauli, Panhethi and Sikandra Rao areas, respectively.

Table-21 : Chemical characteristics of Reh soils of Aliqarh District (U.P.).

Depth (cm)	Ca <sup>++</sup>	Mg <sup>++</sup>	Na <sup>+</sup>	K <sup>+</sup>	Saturation Extract (meq/litre)				SAR	ESP
					CO <sub>3</sub> <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>-</sup>		
<u>Total</u>										
0-0-43.1	1.39	1.05	130.38	0.23	10.5	123.70	31.25	0.01	113.04	63.34
43.1-60.3	1.20	0.80	154.31	2.30	6.1	113.51	22.10	0.40	135.24	66.48
60.3-70.3	1.58	0.33	133.81	0.13	-	110.29	-	0.98	110.92	61.93
70.3-100.3	1.0	0.32	130.80	0.68	2.3	15.50	-	0.60	103.81	61.42
100.3-130.3	1.53	0.70	131.15	0.10	7.3	50.13	-	0.04	124.09	64.50
<u>Jawan</u>										
0-30	1.0	1.20	25.14	0.20	1.10	12.0	1.03	0.12	16.39	18.64
30-70	1.0	1.00	45.3	1.02	0.0	0.60	61.13	0.01	27.67	22.00
70-104.1	1.0	0.07	52.3	1.00	0.01	0.71	63.18	0.11	47.06	40.30
104.1-110	11.41	20.10	66.5	1.20	0.1	10.14	50.15	0.10	22.3	24.48
110-140	6.16	9.3	85.39	1.20	0.6	16.10	55.16	0.10	30.77	30.60
<u>Langipur</u>										
0-5	1.80	0.85	148.10	0.51	30.10	120.1	1.10	0.10	127.93	65.20
5-86	1.86	0.85	110.33	0.04	10.05	141.01	1.90	0.01	94.78	58.07
86-135	1.69	0.90	140.18	0.01	16.38	122.13	1.13	0.04	123.18	64.34
135-185	1.60	0.51	90.10	0.05	24.10	140.11	1.03	0.02	86.90	55.93
185	1.31	0.19	99.50	0.11	68.19	17.10	1.33	0.01	114.80	62.69
<u>Atrguli</u>										
0-26	3.20	0.10	30.45	0.30	-	4.09	18.15	0.68	18.70	20.83
26-37.8	2.15	0.45	25.46	0.01	20.57	1.03	20.81	0.25	18.97	21.08
37.8-45.2	2.18	1.80	33.19	0.12	18.20	33.51	12.48	0.11	21.01	22.91
45.2-59.0	2.20	0.19	28.18	0.11	-	33.38	16.12	0.89	21.60	23.43
59.0-105	1.90	0.57	34.38	0.19	15.68	4.13	31.00	0.69	20.45	22.42
<u>Pinhetli</u>										
0-10.3	2.00	0.58	129.50	0.30	-	124.70	1.58	0.15	114.01	62.53
10.3-51.2	1.50	0.90	130.12	0.40	-	68.10	1.13	0.13	118.78	63.49
51.2-70.9	2.60	1.21	147.90	0.01	-	53.12	1.05	0.12	105.70	60.69
70.9-121.3	1.00	0.50	118.80	0.13	12.38	52.09	2.35	0.50	137.17	66.79
121.3	1.00	1.10	112.30	0.15	25.10	10.10	3.15	0.09	98.40	59.01
<u>Sikandra Rao</u>										
0-20.0	9.10	4.30	0.19	0.18	-	16.80	35.10	0.01	17.50	19.78
20.0-41.8	0.98	0.50	18.30	0.10	0.01	3.19	42.02	-	21.27	23.14
41.8-65.3	1.31	1.50	20.68	0.19	3.02	6.05	38.00	-	19.03	21.14
65.3-83.0	2.18	2.08	41.89	1.39	-	5.49	42.31	-	28.70	29.11
83.0-121.8	2.10	2.00	34.18	1.28	-	11.35	15.16	-	23.87	25.34

### Soluble Anions

The soluble carbonate is variable. It varies from 6.10 to 95.30 meq/lit, 0.01 to 1.10 meq/lit, 10.05 to 68.19 meq/lit, 15.68 to 20.57 meq/lit, 12.38 to 25.1 meq/lit, 0.01 to 3.02 meq/lit in Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao areas, respectively.

The bicarbonates range from 15.50 to 123.70 meq/lit, 12 to 20.71 meq/lit, 17.10 to 141.01 meq/lit, 4.09 to 33.51 meq/lit, 10.10 to 68.10 meq/lit, 3.19 to 16.80 meq/lit in Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao areas respectively.

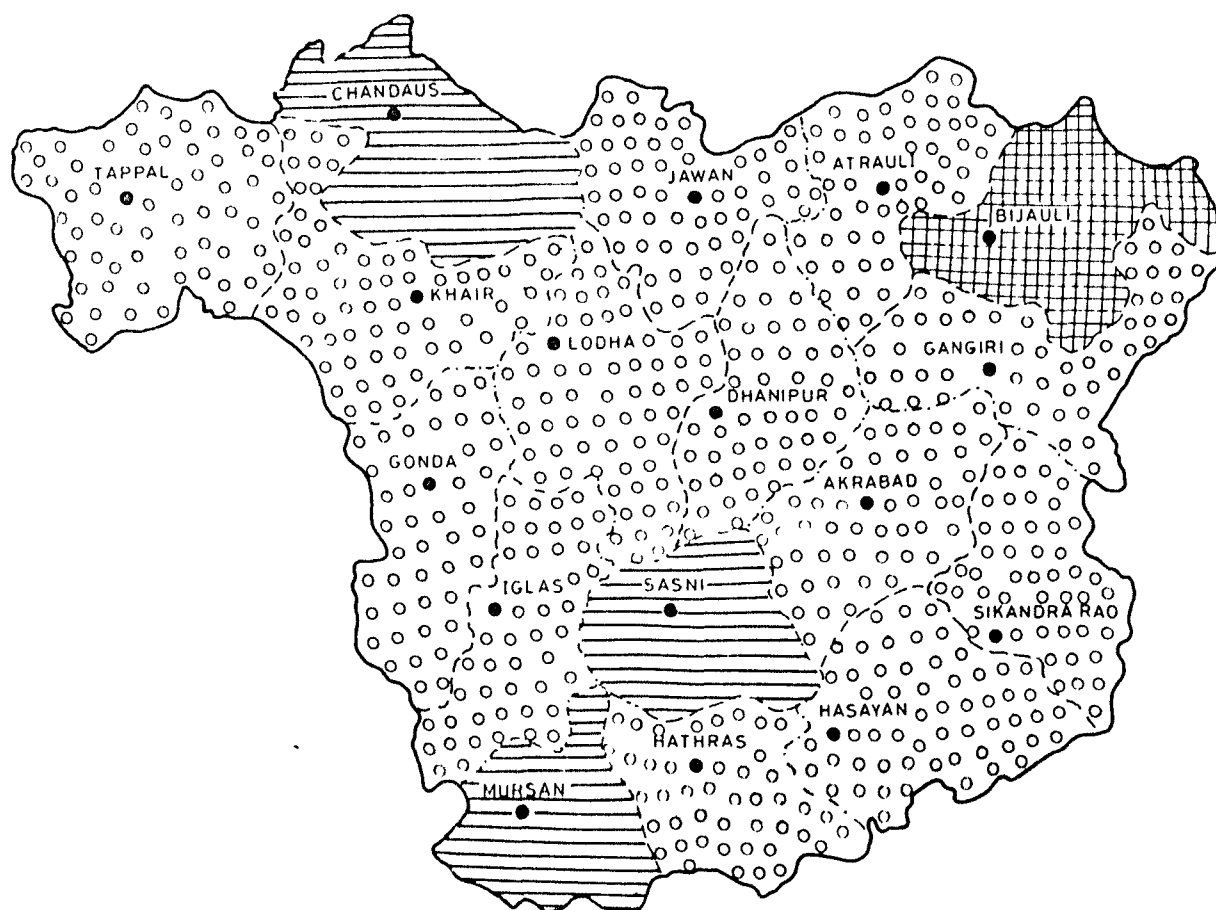
The chloride anion vary from 1.10 to 1.90 meq/lit, 16.12 to 31.00 meq/lit, 1.05 to 3.15 meq/lit, 15.16 to 42.31 meq/lit in Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao, areas respectively.

The sulphate anion is present in minor amount and vary from 0.01 to 0.98 meq/lit, 0.01 to 0.12 meq/lit, 0.01 to 0.10 meq/lit, 0.11 to 0.89 meq/lit, 0.05 to 0.15 meq/lit and 0.01 meq/lit in Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao areas respectively.







### Sodium Adsorption Ratio and Exchangeable Sodium Percentage

Sodium adsorption ratio varies from 108.81 to 135.33, 16.39 to 47.06, 86 to 127.93, 18.70 to 21.60, 98.49 to 137.17,

# FERTILITY (N,P,K, NUTRIENTS) STATUS OF SOILS OF ALIGARH DISTRICT, U.P. 1985-86



## LEGEND

-  M-M-H (MEDIUM-MEDIUM-HIGH)
-  VL-L-H (VERY LOW-LOW-HIGH)
-  VL-VL-H (VERY LOW-VERY LOW-HIGH)
-  BLOCK BOUNDARY
-  TEHSIL BOUNDARY
-  BLOCK HEAD QUATERS

0 2 4 KM

SOURCE : REGIONAL SOIL LABORATORY, ALIGARH

FIG. 30

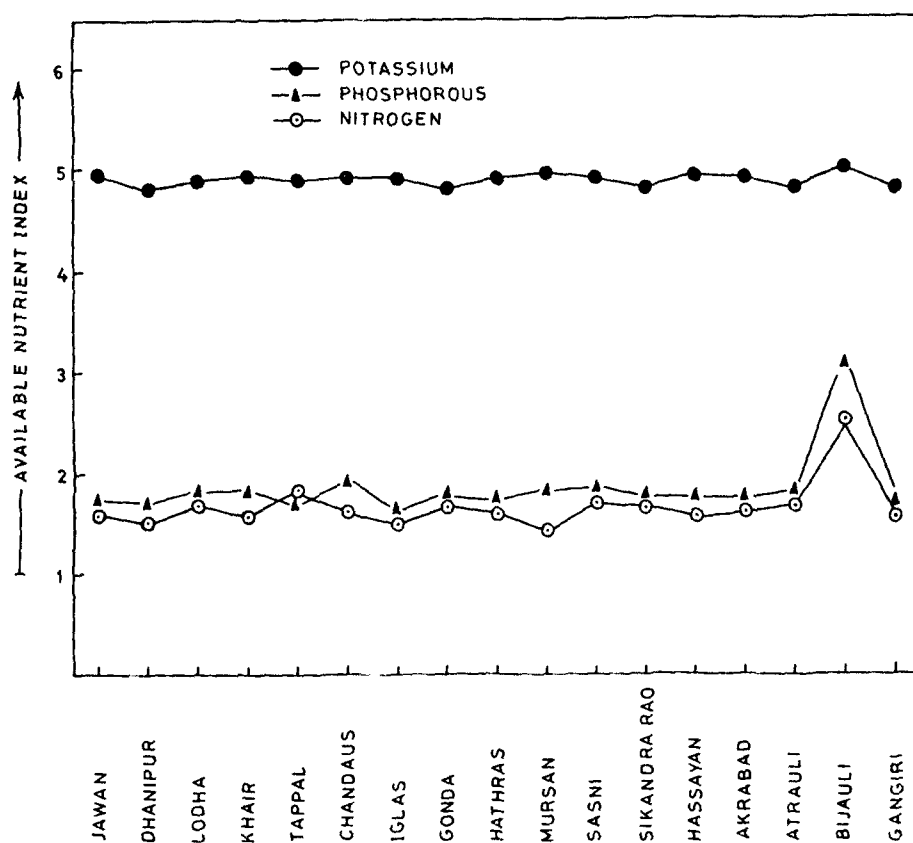


FIG.31 .BLOCKWISE GRAPH SHOWING DISTRIBUTION OF N,P,K STATUS OF SOILS OF ALIGARH DISTRICT ( U P ) 1985 - 86 .



17.58 to 28.70 in the soils at Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao, respectively.

Exchangeable sodium percentage vary from 61.42 to 66.48, 18.64 to 40.30, 55.93 to 65.20, 20.83 to 23.43, 59.01 to 66.79, 19.78 to 29.11 in the soil at Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao, respectively.

#### 7.1.2. Available Nutrients (Table-23)

There is a marked deficiency in the nitrogen (1.43 to 2.46), have moderate to low phosphorus (1.60 to 3.00) and have high potassium (4.72 to 5.00) at Koil, Khair, Iglas, Hathras, Sikandra Rao and Atrauli Tahsils (Figs. 30 & 31).

#### 7.2. MAJOR OXIDE COMPOSITION (Table-22)

##### Silica ( $\text{SiO}_2$ )

The  $\text{SiO}_2$  in the Reh soils vary with depth and range from 48 to 56.21 per cent, 45.25 to 62.25 per cent, 41.98 to 50.65 per cent, 40.38 to 60.30 per cent, 48.31 to 59.85 per cent and 50.13 to 55.84 per cent in Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao areas, respectively (Fig. 32).

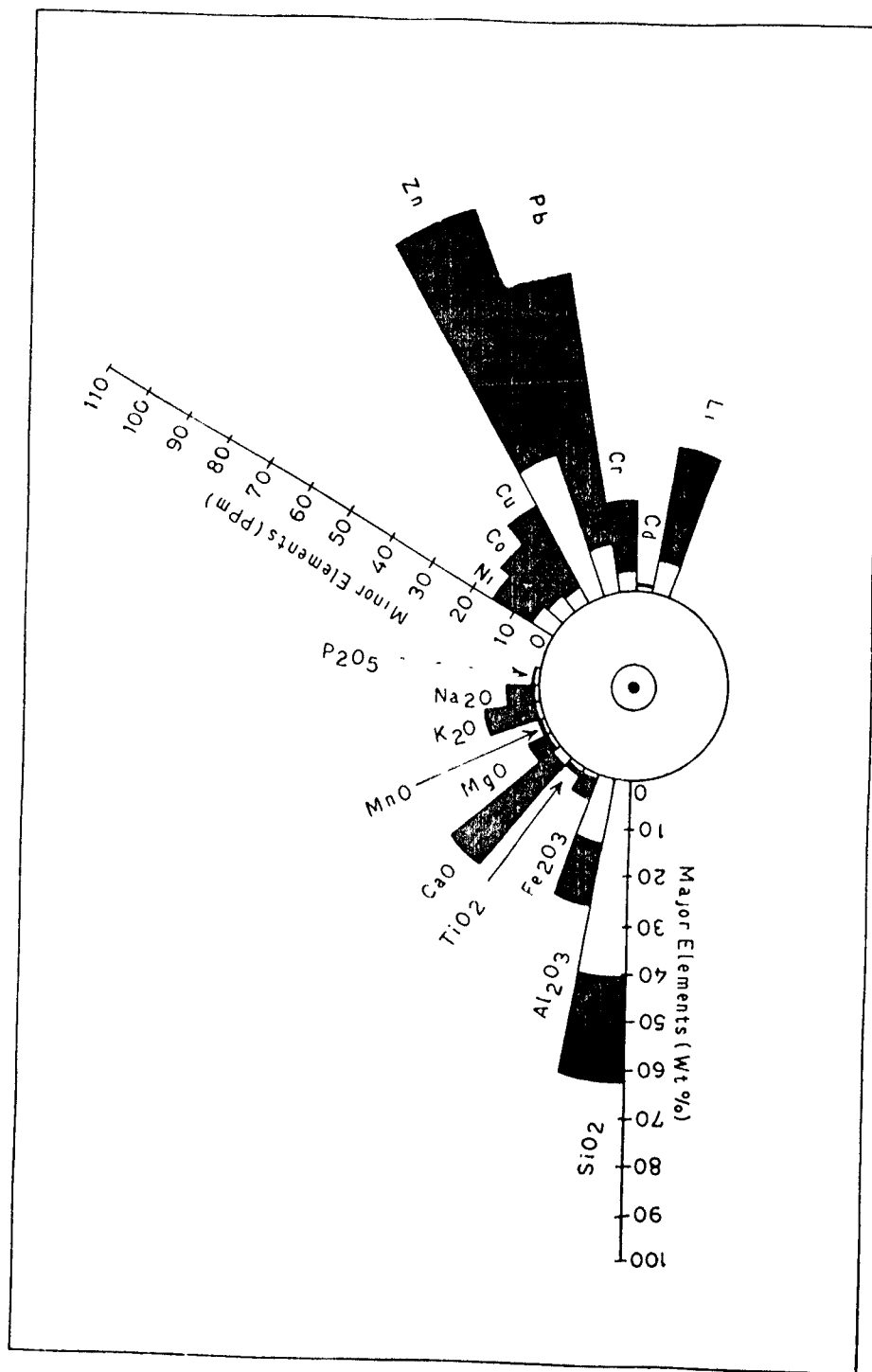


FIG.32 . CIRCULAR DIAGRAM SHOW NG VARIATION OF ELEMENTS IN 'REH' SOILS OF DISTRICT ALIGARH.

Table-23 : Blockwise Fertility (Nutrients Nitrogen, Phosphorus and Potassium) status of soils of Aligarh District, U.P., 1985-86.

Tahsil	Blocks	Macro Nutrient Index %			Fertility status (Nutrient Index Division)		
		Av. N	Av. P	Av. K	N	P	K
Koil	Jawan	1.55	1.69	4.98	VL	VL	H
	Dhanipur	1.45	1.70	4.80	VL	VL	H
	Lodha	1.70	1.80	4.90	VL	VL	H
Khair	Khair	1.53	1.78	4.92	VL	VL	H
	Tappal	1.75	1.65	4.86	VL	VL	H
	Chandaus	1.56	1.87	4.87	VL	L	H
Iglas	Iglas	1.47	1.60	4.97	VL	VL	H
	Gonda	1.73	1.74	4.79	VL	VL	H
Hathras	Hathras	1.64	1.61	4.86	VL	VL	H
	Mursan	1.43	1.82	4.96	VL	L	H
	Sasni	1.66	1.83	4.84	VL	L	H
Sikandra Rao	Sikandra Rao	1.69	1.65	4.77	VL	VL	H
	Hasayan	1.52	1.72	4.97	VL	VL	H
	Akrabad	1.63	1.72	4.85	VL	VL	H
Atrauli	Atrauli	1.71	1.69	4.83	VL	VL	H
	Bijauli	2.46	3.00	5.00	M	M	H
	Gangiri	1.61	1.61	4.72	VL	VL	H

VL = Very Low (0.0 - 1.8)  
 L = Low (1.9 - 2.4)  
 M = Medium (2.5 - 3.4)  
 MH = Medium High (3.5 - 4.2)  
 H = High (4.3)

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TABLE 22 CHEMICAL ANALYSIS OF 'RKH' SOILS OF ALIGARH DISTRICT(U.P.)

LOCATION DEPTH(CM)	MAJOR ELEMENTS (wt%)										TRACE ELEMENTS (ppm)									
	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	TI02	CaO	MgO	MnO	K <sub>2</sub> O	Na <sub>2</sub> O	P <sub>2</sub> O <sub>5</sub>	Ni	Co	Cu	Zn	Pb	Cr	Cd	Li		
Tappa																				
0-21	49.21	19.55	3.16	0.490	2.00	3.42	0.692	2.50	5.80	0.22	10	11	12	64	27	9	<1	23		
48-60.5	48.00	20.01	4.93	0.570	1.40	3.42	0.773	2.70	1.80	0.32	12	12	19	85	27	14	<1	33		
60-90.3	54.35	19.15	5.40	0.513	1.68	3.80	0.776	3.00	2.00	0.30	11	12	19	85	38	13	<1	32		
90-125.3	45.13	20.25	3.90	0.475	3.36	3.80	0.914	2.10	2.20	0.30	10	10	15	69	35	18	<1	23		
125-3-130.1	56.21	24.35	1.71	0.247	2.00	0.60	0.373	1.40	1.20	0.24	5	7	6	33	62	4	<1	7		
Jawan																				
0-30	62.65	15.25	3.22	0.595	2.52	1.60	0.534	2.70	3.40	0.1	8	10	14	50	23	10	<1	23		
30-70	55.77	19.00	2.65	0.4370	2.42	1.81	0.530	1.70	1.80	0.26	15	8	04	31	11	5	<1	15		
70-94.1	58.55	20.45	1.71	0.6930	1.40	0.40	1270	2.70	4.80	0.29	13	18	14	71	11	13	<1	22		
94-110	45.25	13.15	2.49	0.2850	18.50	13.10	0.810	1.80	0.20	0.21	10	12	18	47	58	18	<1	29		
110-129	59.64	13.5	3.72	0.6450	3.20	2.20	0.980	2.10	1.60	0.24	11	13	18	66	15	12	<1	31		
Panjipur																				
0-5	42.18	1.5	2.65	0.2150	2.00	3.62	0.850	1.10	0.80	0.16	8	8	9	41	38	6	<1	14		
5-86	50.05	11.52	3.60	0.3420	15.14	5.29	2.150	2.10	0.80	0.18	11	11	23	52	31	11	<1	31		
86-135	47.57	20.21	7.7	0.5320	0.33	3.42	0.875	3.00	1.40	0.21	11	12	20	76	62	19	<1	31		
135-185	44.00	14.51	2.73	0.3930	5.35	1.81	0.655	1.90	1.00	0.25	19	7	12	39	35	7	<1	14		
185>	41.00	13.50	2.72	0.200	23.50	5.45	1243	1.40	0.20	0.21	10	12	18	46	54	6	<1	12		
Atrauli																				
0-26	51.10	16.29	2.98	0.5800	5.04	2.01	0.640	2.20	2.20	0.26	10	14	13	52	38	8	<1	19		
26-39.8	50.30	17.20	2.60	0.270	5.60	2.62	0.640	2.10	1.80	0.29	10	11	12	48	27	13	<1	20		
39-8-45.2	52.00	16.30	2.32	0.3500	5.50	2.40	0.640	2.20	7.20	0.25	8	18	9	39	23	11	<1	17		
45-2-59.0	47.30	13.00	1.51	0.1995	27.19	5.24	1.010	12.20	1.80	0.21	10	14	12	37	31	7	<1	17		
59.0-105	67.3	20.00	3.20	0.3895	1.68	1.80	0.515	2.60	0.60	0.30	10	11	11	71	31	11	<1	19		
Pannethi																				
0-10.3	59.85	20.00	2.17	0.3800	1.00	1.20	0.320	2.10	2.20	0.18	6	5	6	36	42	6	<1	13		
10-3-51.2	55.35	20.15	3.00	0.485	1.38	1.20	0.570	2.50	2.00	0.26	9	10	14	50	58	10	<1	19		
51-2-80.9	57.85	22.31	2.11	0.4750	1.40	2.00	0.443	2.00	2.00	0.17	7	9	6	48	54	19	<1	16		
80-9-121.3	55.30	20.50	1.67	0.2470	1.76	1.00	0.312	1.90	4.20	0.25	5	5	22	27	46	6	<1	18		
121.3>	44.31	13.20	1.20	0.5220	5.07	2.01	0.678	2.10	1.80	0.17	11	14	11	67	62	10	<1	27		
Sikandra-Rac																				
0-20.0	50.13	10.25	3.13	0.5130	1.10	2.62	0.665	2.70	1.60	0.21	8	9	11	52	23	9	<1	23		
20-41.8	52.14	10.25	2.67	0.5610	2.50	2.21	0.500	2.20	2.20	0.29	9	13	11	43	42	7	<1	15		
41-8-65.3	50.69	20.10	3.31	0.3420	1.40	3.40	0.330	1.10	1.40	0.25	10	8	12	38	31	21	<1	13		
65-3-83.0	55.84	16.29	2.40	0.5415	1.90	1.40	0.570	2.40	2.00	0.24	11	12	8	38	31	9	<1	15		
83.0-121.8	51.54	18.39	2.73	0.4560	5.64	2.80	0.650	2.60	0.80	0.24	8	10	10	48	31	9	<1	12		

### Aluminium Oxide ( $\text{Al}_2\text{O}_3$ )

The distribution of  $\text{Al}_2\text{O}_3$  in soils vary from 19.15 to 24.35 per cent, 15.25 to 20.95 per cent, 13.50 to 20.21 per cent, 14.69 to 20.89 per cent, 19.20 to 26.56 per cent, 16.29 to 20.12 per cent in Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao areas, respectively.

### Iron Oxide ( $\text{Fe}_2\text{O}_3$ )

$\text{Fe}_2\text{O}_3$  presented in the Reh soils vary from 1.74 to 5.40 per cent, 2.05 to 4.71 per cent, 2.05 to 4.77 per cent, 1.91 to 3.89 per cent, 1.67 to 4.28 per cent and 2.67 to 3.31 per cent in Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao areas, respectively.

### Titanium Oxide ( $\text{TiO}_2$ )

$\text{TiO}_2$  show a broadly uniform distribution in soils from 0.247 to 0.5700 per cent, 0.285 to 0.646 per cent, 0.218 to 0.532 per cent, 0.199 to 0.580 per cent, 0.247 to 0.522 per cent and 0.342 to 0.561 per cent at Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao areas, respectively.

### Calcium Oxide (CaO)

The amount of CaO was found to be variable in the Reh soils. It varies from 1.40 to 3.36 per cent, 1.40 to 18.50 per cent, 5.65 to 28.60 per cent, 1.68 to 27.19 per cent, 1.40 to 8.97 per cent and 1.40 to 5.04 per cent at Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao areas, respectively.

### Magnesium Oxide (MgO)

It varies from 0.60 to 3.80 per cent, 0.40 to 13.10 per cent, 0.40 to 13.10 per cent, 1.81 to 5.45 per cent, 1.80 to 5.24 per cent, 1.00 to 2.01 per cent and 1.40 to 3.40 per cent in the soils at Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao areas, respectively.

### Manganese Oxide (MnO)

MnO is broadly uniform and vary from 0.037 to 0.091 per cent, 0.053 to 0.127 per cent, 0.065 to 0.215 per cent, 0.0545 to 0.101 per cent, 0.031 to 0.068 per cent and 0.0500 to 0.0665 per cent at Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao areas, respectively.

### Potassium Oxide ( $K_2O$ )

$K_2O$  in Reh soils of Aliqarh range from 1.40 to 3.00 per cent, 1.70 to 2.70 per cent, 1.40 to 3.00 per cent, 1.70 to 2.70 per cent, 1.40 to 3.00 per cent, 2.10 to 12.20 per cent, 1.90 to 2.50 per cent and 1.10 to 2.70 per cent at Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao, respectively.

### Sodium Oxide ( $Na_2O$ )

$Na_2O$  in Reh soils range from 1.20 to 5.80 per cent, 0.20 to 4.80 per cent, 0.20 to 1.40 per cent, 0.80 to 7.20 per cent, 1.80 to 4.20 per cent and 0.80 to 2.20 per cent at Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao areas, respectively.

### Phosphate ( $P_2O_5$ )

The distribution of  $P_2O_5$  in various profiles of Reh soils vary from 0.22 to 0.32 per cent, 0.21 to 0.29 per cent, 0.16 to 0.25 per cent, 0.21 to 0.30 per cent, 0.17 to 0.26 per cent and 0.21 to 0.29 per cent at Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao areas, respectively.

### 7.3. TRACE ELEMENTS COMPOSITION

#### Nickel

The distribution of nickel is nearly uniform in soil profiles varying from 5 to 12 ppm, 8 to 15 ppm, 8 to 10 ppm, 8 to 10 ppm, 6 to 11 ppm, and 8 to 11 ppm at Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao, respectively.

#### Cobalt

Cobalt vary from 5 to 18 ppm in the soils at Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao respectively.

#### Copper

The Cu-content varies in soils of Aligarh area from 6 to 19 ppm, 4 to 18 ppm, 9 to 23 ppm, 9 to 13 ppm, 6 to 22 ppm and 8 to 12 ppm at Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao, respectively.

#### Zinc

The Zn content varies from 33 to 85 ppm, 31 to 66 ppm, 41 to 76 ppm, 37 to 71 ppm, 27 to 67 ppm and 38 to 52 ppm at



Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao, respectively.

#### Lead

Pb is a toxic element and varies from 27 to 62 ppm, 11 to 58 ppm, 31 to 62 ppm, 31 to 38 ppm, 42 to 62 ppm, 23 to 42 ppm at Tappal, Jawan, Panjipur, Atrauli, Panhethi, Sikandra Rao, respectively.

#### Chromium

Chromium is the hazardous element. It varies from 4 to 14 ppm, 5 to 13 ppm, 6 to 19 ppm, 7 to 13 ppm, 6 to 10 ppm and 7 to 21 ppm in the soils at Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao, respectively.

#### Cadmium

The distribution of cadmium shows a regular trend in the soils. It is less than one in all the soil horizons.

#### Lithium (Fig. 32)

Li is not uniformly distributed and varies from 7 to 33

ppm, 15 to 31 ppm, 12 to 31 ppm, 17 to 20 ppm, 8 to 27 ppm & 15 to 31 ppm at Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao, respectively.

#### 7.4. DISCUSSION

On the basis of lithostratigraphy, the alluvial soils at Aligarh can be classified as follows :-

1. Ganga Khadar soils
2. Eastern upland soils
3. Central lowland soils
4. Western upland soils
5. Trans-Yamuna khadar
6. Yamuna khadar soils

#### 7.5. THE PROBLEM OF SALINITY AND ALKALINITY

The central lowland areas are water-logged. Salt crust is found on the surface during the dry seasons in these areas. It is further observed that the system of canal irrigation and accumulation salt in the soils correlated very well. It has been found that bad drainage and trough-like topography are the main contributing factors in the degradation of soils. There is a parallel development of 'reh' along the upper Ganga canal (Fig. 17).

## Texture

Analysis of soil profiles show that the clay and silt contents increase with depth at Tappal while at Jawan it becomes silty clay loam to loamy sand, the top has higher content of silt. In Panjipur the top surface is mostly clayey with a zone of  $\text{CaCO}_3$  kankars about 49 cm thick. The thick kankar zone is impermeable and acts as a barrier to percolating water. Under this kankar zone is a layer of sandy loam. A second or the basement zone of kankar lies at 185 cm depth.

At Atrauli, the loam to silty loam soils are almost totally devoid of carbonate concretions. The silt content increases with depth, but at Panhethi it is silty loam on the surface becoming sandy with depth. A kankar zone occurs at 10.3 cm depth. Like Atrauli, at Sikandra Rao too it is loamy on the surface and silty caly at depth.

## pH (Hydrogen ion Centrations)

Although pH varies between 2 to 12,,majority of the soils are neutral. The metal uptake by plants and solubility of salts increases with pH of the soil. However, pH itself is a function of dissolved  $\text{CO}_2$ . The pH of most Aligarh soils is above 8.5 which increases the solubility of salts. This value is close enough to those of Ganga and Yamuna river soils and water. Fireman and Wadleigh (1951) observed that when the pH of

saturated soil paste is (i) 8.5 or more, exchangeable sodium percentage is 15 or more and alkaline earth carbonate are present, (ii) slightly less than 8.5, exchangeable sodium percentage is within 15, (iii) less than 7.5, no alkaline-earth carbonates are found, and (iv) less than 7.0, there is significant amount of exchangeable hydrogen.

The soil profiles at Tappal show the pH range from 9.8 to 10.95 indicating a highly alkaline nature. Those at Jawan show pH from 8 to 8.5, Panjipur 8.8 to 10.9, Atrauli 9.3 to 10.5, Panhethi 8.9 to 9.8 and Sikandra Rao 8.0 to 8.9.

Thus the soils at Tappal are highly alkaline, resembling Hilgard's 'black alkali' soils or the Russian solonetz. Similarly, soils at Panjipur, Atrauli, and Panhethi also fall under alkaline (non-saline category). On the other hand, soils at Jawan and Sikandra Rao may be classified as saline-alkaline.

The oxides of calcium, magnesium, sodium and potassium each make up about 1 to 2 per cent and the total of these constitute about 5 to 7 per cent of most soils of humid region. The oxides of manganese, phosphorus generally, constitute a fraction of a per cent. The percentage of Si, Al, Fe, Ti, Na and K in the ash of organic soils are not much different from those in mineral soils. Table-22 gives the chemical analysis of the saline-alkaline soils of Tappal, Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao areas.

### 7.6. MAJOR OXIDES

The major chemical constituents are described as follows :-

#### Silica ( $\text{SiO}_2$ )

The percentage of silica in soils ranges from 45.13 to 56.21 at Tappal, 45.25 to 62.65 at Jawan, 41.98 to 50 at Panjipur, 40.38 to 60.30 at Atrauli, 48.31 to 59.85 at Panhethi and 50.13 to 55.64 at Sikandra Rao. This is because silica is least soluble during weathering and erosion. Most of the silica remains locked in quartz, clays and other sheet silicates (Figs. 33 & 34).

Quartz may, however, dissolve slightly and form silicate anions or hydrosol. The solubility of silica depends on the pH of the solution. The higher the pH, the greater the amount of silica which goes into solution.

Silica is essential for certain lower plants and beneficial for the higher one. Its uptake is proportional to the rate of transpiration. Among other uses, silica increases resistance in plants (Hutton and Norrish, 1974), photosynthesis (Yuan and Chang, 1978), counteracts manganese toxicity (Vorm and Diest, 1979) and is good for growth of rice and tomato (Miyake and Takahashi, 1978).

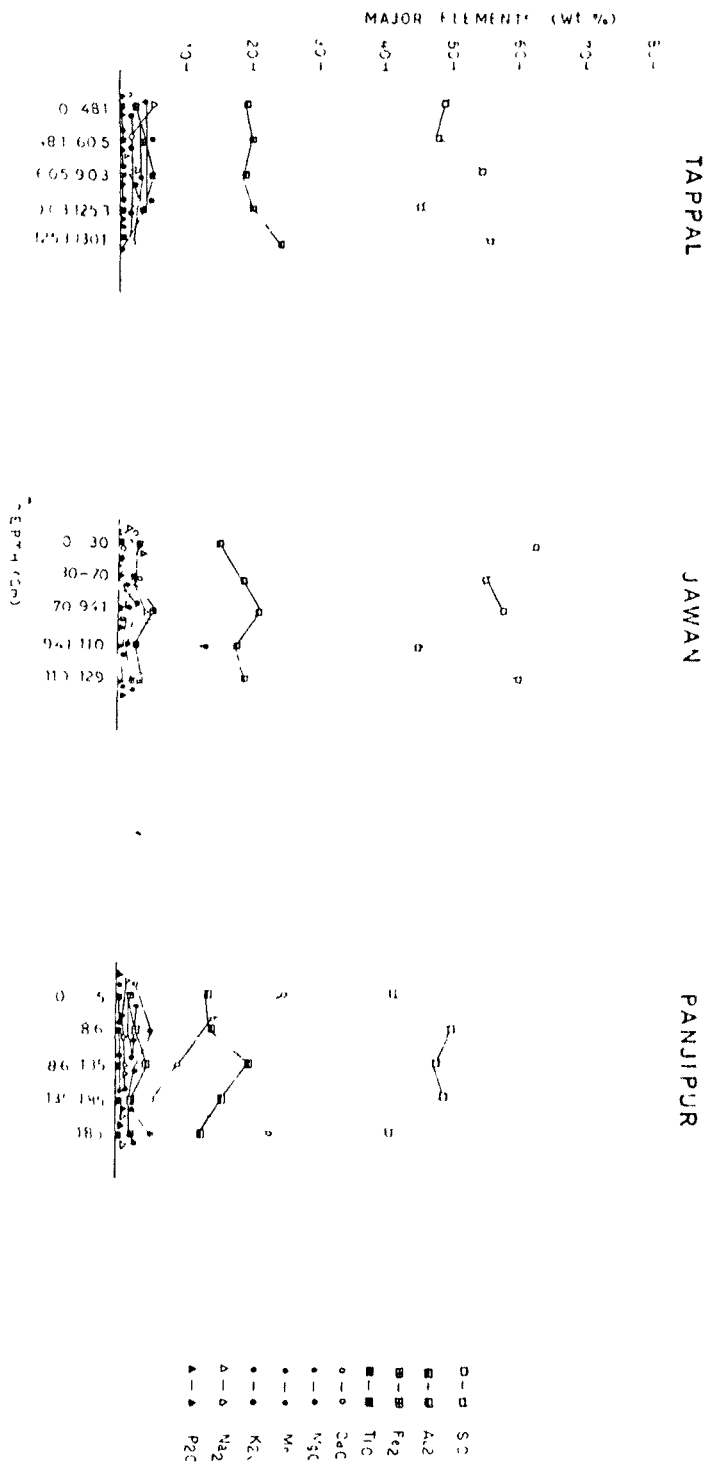
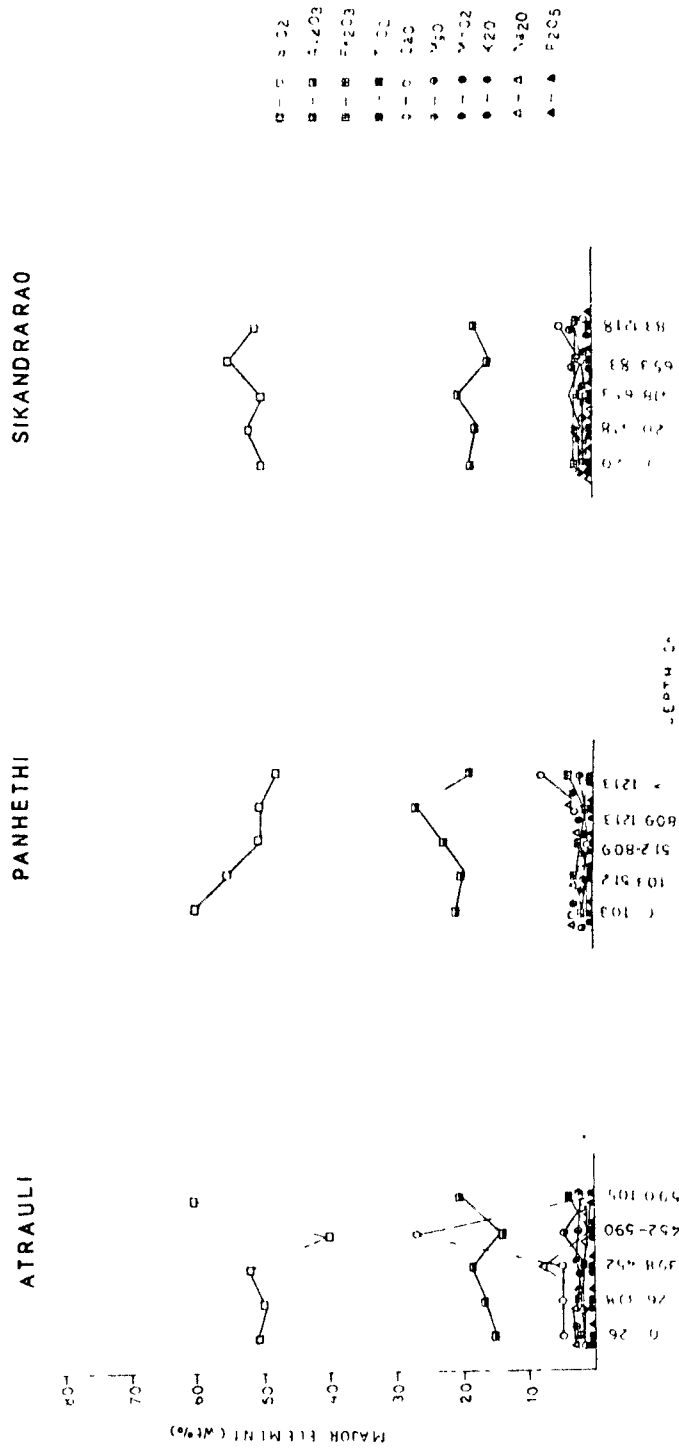


FIG. 33- Vertical distribution of elements in soil profiles



### Alumina ( $\text{Al}_2\text{O}_3$ )

The alumina content shows some variation. Their range is as follows :-

Tappal 19.15 to 24.35 per cent, Jawan 15.25 to 20.95 per cent, Panjipur 13.50 to 20.21 per cent, Atrauli 14.69 to 20.89 per cent, Panhethi 19.20 to 26.56 per cent and Sikandra Rao 18.25 to 20.12 per cent.

At the onset of chemical weathering the aluminosilicate minerals dissolve completely. Aluminium is soluble both in acid ( $\text{pH} < 4$ ) as well as in basic ( $\text{pH} > 9$ ) media but gets precipitated as hydroxide in neutral solutions or due to evaporation. Carbon dioxide may act as neutralizing agent. If silica is also present, aluminium may react with it and crystallize clay minerals (illite, kaolinite). Some of the two may also coagulate as hydrogels. Replacement of  $\text{Al}^{3+}$  by  $\text{Fe}^{3+}$ ,  $\text{Mg}^{2+}$ , alkali metals and alkaline earth metals may take place. Aluminium is essential for the growth of plants. Since available aluminium is present only in the acidic soils, the latter is favourable for plant growth.

### Total Iron Oxides ( $\text{FeO} + \text{Fe}_2\text{O}_3$ )

The soils are rather high in iron. The total iron oxide per cent show the following range :-



Tappal 1.74 to 5.40, Jawan 2.05 to 4.71, Panjipur 2.05 to 4.77, Atrauli 1.91 to 3.89, Panhethi 1.67 to 4.28 and Sikandra Rao 2.67 to 3.31.

Iron in soils generally occurs as hydrous oxide, but can enter freely the 2 : 1 to 2 : 2 layer silicate structures including biotite and vermiculite. A small percentage of iron occurs in pyroxenes and amphiboles.

The stage of oxidation plays an important role - it reacts easily during weathering leading to oxidation and formation of ferric hydroxide/oxide. Oxidation and reduction are reversible. Oxidation under low pH ( $\approx 3$ ) promotes precipitation, whereas, reduction at high pH ( $> 7$ ) promotes solution of iron.

During oxidation phosphorus too gets fixed as ferric phosphate or ferric phosphoric acid. This explains the high iron in stable state in highly porous and poorly drained soils. In organic-rich soils iron is reduced and mobilized and, thereby, gets concentrated in the lower layers of soil profile.

#### Titania ( $\text{TiO}_2$ )

$\text{TiO}_2$  content in the soils analysed gave the following range :-

Tappal 0.24 to 0.57 per cent, Jawan 0.28 to 0.89 per cent, Panjipur 0.21 to 0.53 per cent, Atrauli 0.19 to 0.58

per cent, Panhethi 0.24 to 0.52 per cent and Sikandra Rao 0.34 to 0.56 per cent.

Titanium oxide is relatively resistant to weathering. This makes titanium increase in soils due to leaching out of other elements. The titanium ( $\text{Ti}^{4+}$ ) occurs in the lattice of rutile and ilmenite. Phlogopites and biotites may also contain some  $\text{Ti}^{3+}$ .

#### Lime ( $\text{CaO}$ )

The  $\text{CaO}$  varies over a wide range. Locality-wise their range is as follows :-

Tappal 1.40 to 3.36 per cent, Jawan 1.40 to 4.20 per cent, Panjipur 5.65 to 28.60 per cent, Atrauli 1.68 to 27.19 per cent, Panhethi 1.40 to 8.97 per cent and Sikandra Rao 1.40 to 5.04 per cent. In general, accumulation of  $\text{CaO}$  is maximum in the lower horizons (kankar zones). However, in arid regions, its accumulation is maximum nearer the surface.

The source of calcium in soils are mainly minerals like plagioclase, augite, hornblende and epidote. During chemical weathering calcium is liberated and forms calcium bicarbonate. The sodium-calcium ratio in soil and minerals, generally, shows a marked similarity. Unlike sodium, calcium is not adsorbed significantly by clays and, consequently, the bulk of the calcium liberated do not form hydrolyzates.

Pedogenic  $\text{CaCO}_3$  is mainly calcite. The leaching water carries  $\text{Ca}(\text{HCO}_3)_2$  downward to a certain depth from which the water is removed by plant roots leaving behind  $\text{CaCO}_3$ .

From agricultural point of view calcium is beneficial to plants. Fruit ripening is enhanced by calcium treatment (Lougheed, 1979). It also increases membrane permeability, strengthens structure of pectins and produces resistance to fungal infections.

#### Magnesia ( $\text{MgO}$ )

The magnesia content in the soils of Aligarh varies widely as follows :-

Tappal 0.60 to 3.80 per cent, Jawan 0.40 to 13.10 per cent, Panjipur 1.81 to 5.45 per cent, Atrauli 1.80 to 5.24 per cent, Panhethi 1.0 to 2.01 per cent and Sikandra Rao 1.40 to 3.40 per cent.

Magnesium occurs in evaporates alongwith calcium and alkali metals. Magnesium hydroxide starts precipitating at pH 10. This explains the formation of brucite in alkali soils. Dolomitic limestone might be an important source of Mg in soils.

#### Manganese dioxide ( $\text{MnO}_2$ )

Manganese is present in significant amount as follows :-

Tappal 0.037 to 0.091 per cent, Jawan 0.08 to 0.12 per cent, Panjipur 0.065 to 0.215 per cent, Atrauli 0.054 to 0.101 per cent, Panhethi 0.031 to 0.057 per cent, Sikandra Rao 0.033 to 0.066 per cent.

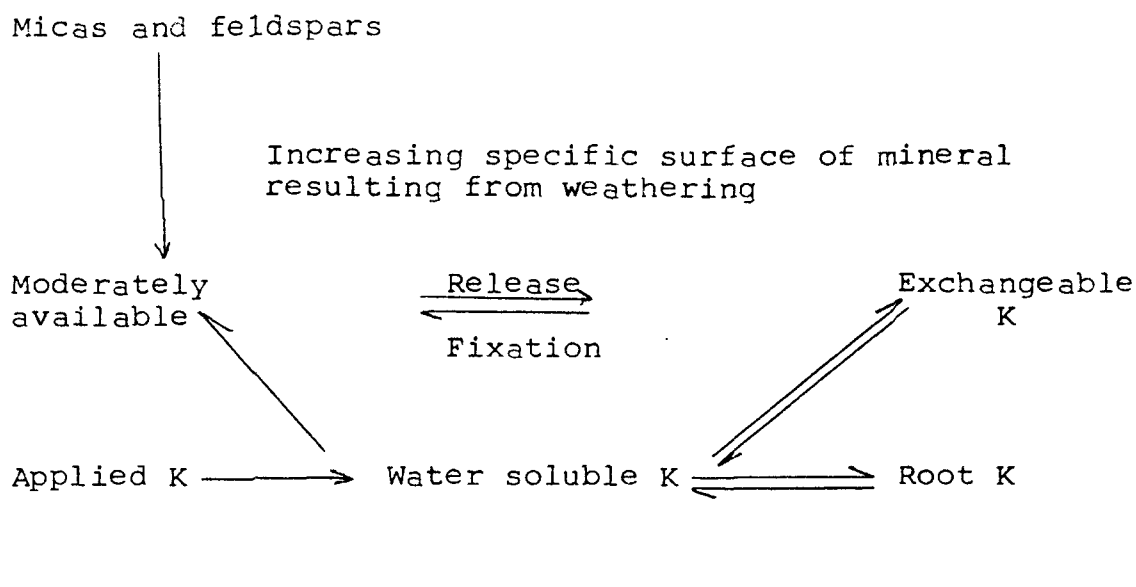
These values are above the critical or the toxicity limit. This is because if soil is well aerated, manganese occurs as oxides and phosphates which, under wet condition, is reduced to soluble divalent form. But otherwise  $Mn^{2+}$  has greater affinity for negatively charged layer silicates which are not extractable by dilute acids (Mukherjee et al., 1973). Sorption studies with bentonite have indicated that two categories of exchangeable  $Mn^{2+}$  exists, one more strongly bound than the other (Basu, 1958). As in the present case high pH, presence of  $CaCO_3$  and low organic matter content are generally considered to exert depressing effect on Mn in soils.

#### Potash ( $K_2O$ )

At Aligarh,  $K_2O$  is in significant amount. The values are as follows :-

Tappal 1.40 to 3.00 per cent, Jawan 1.70 to 2.70 per cent, Panjipur 1.40 to 3.00 per cent, Atrauli 2.10 to 12.20 per cent, Panhethi 1.90 to 2.50 per cent, and Sikandra Rao 1.10 to 2.70 per cent.

From nutrients and agricultural points of view, potassium is high in soils of Aligarh district. Most agricultural soils contain 1 to 2 per cent  $K_2O$ . A close relationship exists between the geomorphology, weathering and  $K_2O$  content in soils. Only a little of exchangeable potassium is available as majority of it resides in K-bearing feldspars and micas. The relationship can be expressed as follows :-



Soda ( $Na_2O$ )

The  $Na_2O$  ranges from 0.1 to 1 per cent in most soils. A decrease in  $Na_2O$  content will reflect weathering away of sodium-bearing minerals, mainly plagioclase feldspar, in soils. On the contrary, high sodium content reflects leaching of soil minerals. In such case sodium occurs in acidic plagioclase and,

in small amounts, in micas, pyroxenes and amphiboles, mainly in the fine sand and silt fractions. The leached out sodium forms  $\text{NaCl}$ ,  $\text{Na}_2\text{SO}_4$  and, sometimes,  $\text{Na}_2\text{CO}_3$  and other soluble salts in the saline and alkaline soils. In sodic soils exchangeable sodium is 15 per cent. On tillage it disperses and develops adverse effects.

#### Phosphorus Pentoxide ( $\text{P}_2\text{O}_5$ )

$\text{P}_2\text{O}_5$  is rather low in the soils of Aligarh area. The values are as follows :-

Tappal 0.22 to 0.32 per cent, Jawan 0.21 to 0.29 per cent, Panjipur 0.16 to 0.25 per cent, Atrauli 0.21 to 0.30 per cent. Panhethi 0.17 to 0.26 per cent and Sikandra Rao 0.21 to 0.28 per cent.

The status of phosphorus is, in general, low throughout the study area. The inorganic phosphorus in alkaline and calcareous soils occurs mainly as calcium phosphate (mainly fluorapatite  $\text{Ca}_{10}(\text{PO}_4)_6\text{F}_2$ ).

Under reducing conditions, vivianite  $\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$ , forms which, being fairly soluble, may be deposited at lower soil levels.

In spite of slow rate of transformation, the availability of phosphates to plants depends on ionic activity.

At high pH, Ca-phosphate is highly maintainable while iron and aluminium phosphates are available more to plants.

#### 7.7. TRACE ELEMENTS (Figs. 35 & 36)

The trace elements affect the soil fertility. Trace metal like Ni, Co, Cu, Zn, Pb, Cr, Cd and Li were studied in the soils of Aligarh. The observations are presented as follows :-

##### Nickel

Nickel ranges from 5 to 12 ppm in Tappal, 8 to 15 ppm in Jawan, 8 to 11 ppm Panjipur, 8 to 10 ppm in Atrauli, 5 to 11 ppm Panhethi and 8 to 11 ppm in Tappal. The observed variation can be ascribed to the parent rock composition and climate. Arid and semi-arid climates favour lighter content of Ni. Nickel generally accumulates in the upper clayey horizons of the soil profile (Pasternack and Glinski, 1969).

##### Cobalt

Co concentration ranges in Tappal and Jawan from 8 to 18 ppm, Panjipur 7 to 12 ppm, Atrauli 8 to 14 ppm, Panhethi 5 to 14 ppm and Sikandra Rao 8 to 13 ppm.

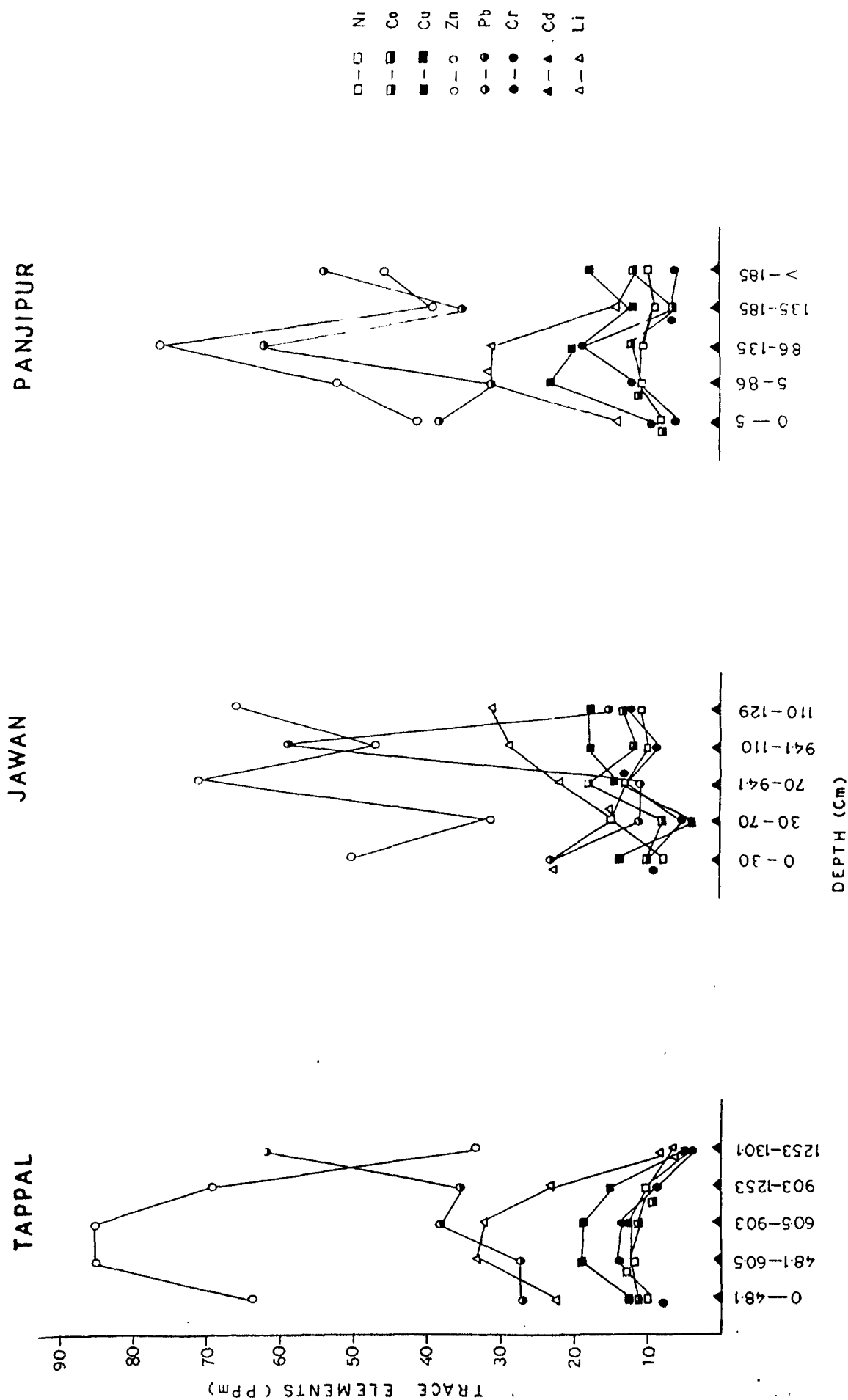


FIG-35--VERTICAL DISTRIBUTION OF ELEMENTS IN SOILS PROFILES



SIKANDRARAO

PANHETHI

ATRAULI

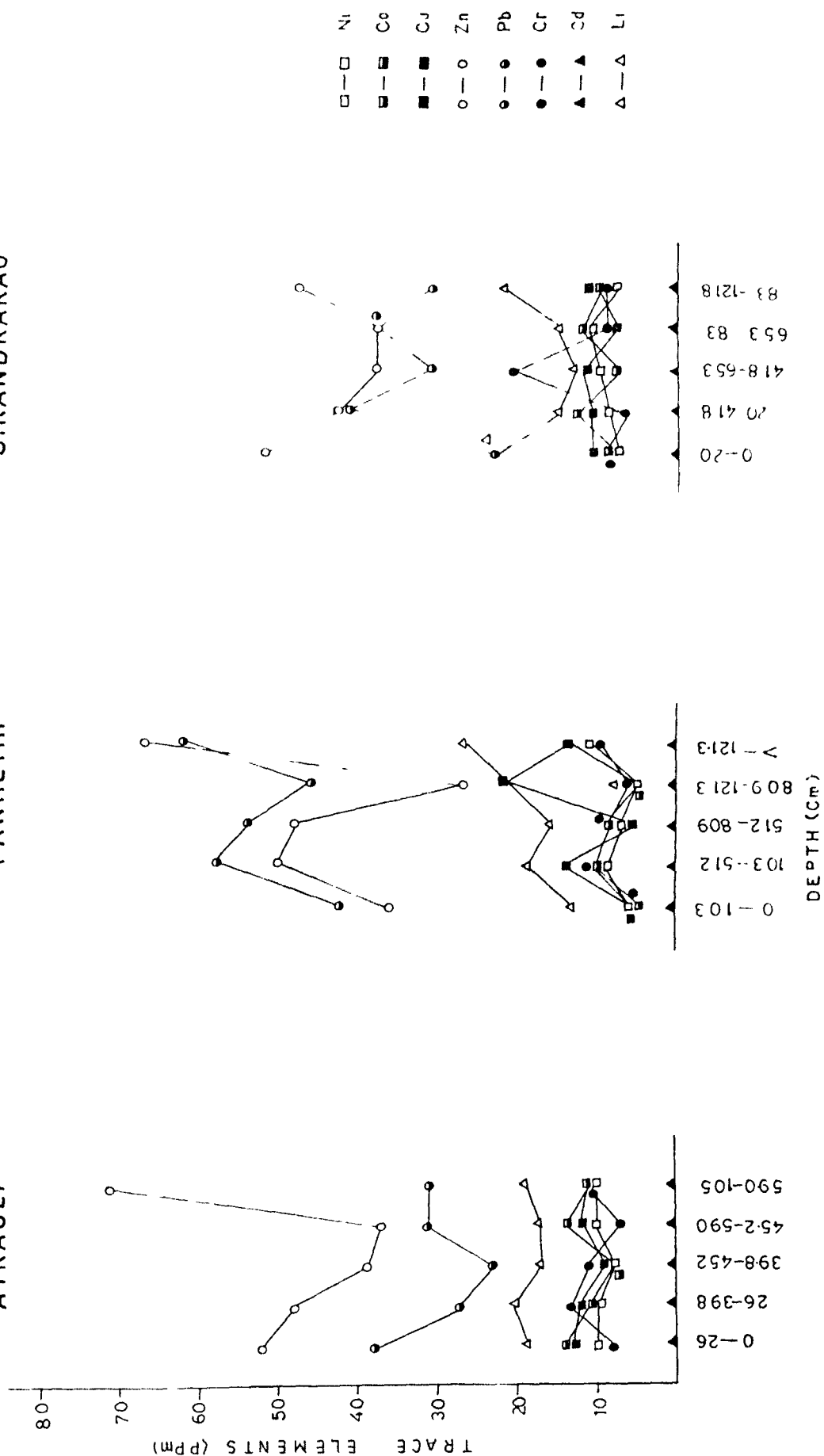


FIG-36 - VERTICAL DISTRIBUTION OF ELEMENTS IN SOILS PROFILES

Like nickel, cobalt content also depends on parent rock composition and climate. The soils of arid and semi-arid regions tend to have higher cobalt content. A distinct relationship exists between cobalt and the humus content. Cobalt is fixed by humus. But cobalt is sorbed by clays which control its distribution in the soil. The alkaline soils are relatively rich in 'available' cobalt.

#### Copper

Copper content in 'Reh' profiles ranges in Tappal 6 to 19 ppm, Jawan 9 to 13 ppm, Panjipur 9 to 23 ppm, Atrauli 9 to 13 ppm, Panhethi 6 to 20 ppm and Sikandra Rao 8 to 12 ppm.

Most saline soils are relatively rich in copper. Copper content of soils varies with the clay content.

#### Zinc

The concentration of zinc ranges as follows :-

Tappal 33 to 85 ppm, Jawan 31 to 66 ppm, Panjipur 39 to 76 ppm, Atrauli 37 to 71 ppm, Panhethi 27 to 67 ppm and Sikandra Rao 38 to 52 ppm.

The zinc concentration of soils vary widely, perhaps, due to their variation in the parent rock. However, it is

biogenic factor which mainly determines the distribution of zinc between the soil horizons. The soil texture and clay content too play some role in it. It has been observed that finer textured soils with clay and loam contains more zinc than the coarser textured soils with sandy material.

#### Lead

The lead contents in the soils studied are as follows :-

Tappal 27 to 62 ppm, Jawan 11 to 58 ppm, Panjipur 21 to 62 ppm, Atrauli 23 to 38 ppm, Panhethi 42 to 63 ppm and Sikandra Rao 23 to 42 ppm.

Lead is extracted from minerals during weathering and transported in solution. Lead forms carbonate in the presence of carbon dioxide and bicarbonate. Vertical variation is not wide though upper horizons often contain more lead (biogenic). It has been observed that Pb content increases with the clay content.

#### Chromium

It ranges in Tappal from 4 to 14 ppm, Jawan 5 to 13 ppm, Panjipur 6 to 19 ppm, Atrauli 7 to 13, Panhethi 6 to 10 ppm and Sikandra Rao 7 to 21 ppm.

Very little of chromium goes into solution during chemical weathering. Consequently, precipitates, oxidates and evaporates are nearly completely devoid of chromium. The total chromium content in soils range from traces to 4000 ppm. The concentration of chromium is mainly controlled by the parent rock composition, as in the case of the soils around Aligarh.

#### Cadmium

The concentration of Cd is  $< 1$  ppm in all the profiles studied. Cadmium is much less abundant than zinc inspite of similarity in their ionic radii ( $\text{Cd}^{2+} = 1.03 \text{ Kx}$  and  $\text{Ca}^{2+} = 1.06 \text{ Kx}$ ). Increased cadmium concentration causes toxicity to crops.

#### Lithium

Lithium content varies from 7 to 33 ppm in Tappal, 15 to 31 ppm in Jawan, 12 to 31 ppm in Panjipur, 17 to 20 ppm in Atrauli, 8 to 27 ppm in Panhethi and 13 to 22 ppm in Sikandra Rao.

Lithium is derived from micas, pyroxenes, amphiboles, etc. But the concentration of lithium varies from soil to soil. Lithium may substitute for aluminium in clay structures. Their distribution in different soils appear to be linked to

the type of soil. Most often these elements accumulate in the upper horizons.

#### 7.8. THE METAL POLLUTION HAZARD AT ALIGARH

Tables-24 & 25 give a comparison of various trace metal values in the soils of Aligarh soils with those of FWPCF (1968) and Ayers and Branson (1978).

It is clear that Ni, Co, Cu, Zn, Pb, Cr, Cd and Li concentrations are above the proposed limits approaching the level of toxicity. Since Aligarh is bounded by the Ganga in the east and the Yamuna in the west, the multifaceted pollutional hazards due to these cannot be overlooked. Aligarh is known as 'Lock City', specialising in the manufacture of locks. This involves excessive use of nickel, chromium, etc. There are no less than 200 small and large factories located in the heart of the city. They are dumping their untreated wastes to the soil thus adding to ground water pollution. Studies reveal that about 300,000 cubic meter of sewage and 20,000 cubic meter of toxic industrial wastes are dumped into Ganga and Yamuna every day. Along the course of Yamuna alone about 3329 industrial units are situated.

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The case of the Ganga is even worse. The Ganga is the most polluted river in India today. The toxic element carried by these rivers ultimately find their way into the soils surrounding them and into which they get accumulated.

Table-24 : Comparison of Trace Metal values of Aligarh with those of FWPCF and others.

Elements	Range at Aligarh (ppm)	FWPCF (1968) Values (ppm)	Ayers and Branson values (1976) (ppm)
Ni	5 - 15	0.50-2.00	0.20-2.00
Co	5 - 18	0.20-10.0	0.05-5.00
Cu	6 - 23	0.20-5.00	0.20-5.00
Zn	31 - 85	5.00-10.0	2.00-10.0
Pb	11 - 62	5.00-10.0	2.00-10.0
Cr	4 - 19	5.00-20.0	0.10-1.00
Cd	< 1		

Table-25 : Guidelines for Irrigation and Soils (Neimenis et al., 1979).

Parameter mg/l or ppm	Irrigation (all soils)	Concentration in Aligarh soils (ppm)
Cadmium	0.05	<1
Chromium	1.00	4 - 19
Cobalt	5.00	5 - 18
Copper	5.00	6 - 23
Iron	20.00	-
Lead	10.00	11 - 62
Manganese	10.00	-
Nickel	2.00	5 - 15
Zinc	10.00	31 - 85

The Ni values are much higher at Tappal and Jawan. It seems that in Jawan, the power generating plant, Central Dairy Farm, Glaxo Chemical and other lock manufacturing industries are the major contributors of nickel in soil. This affects plant growth, and causes dermatitis in human beings.

Co has maximum concentration (18 ppm) at Jawan and minimum (5 ppm) at Panhethi. But these values are above the prescribed limits. The lock manufacturing industries are the main source of their concentration at Aligarh.

The Cu values are much above the critical limit. Various industries, hospitals, power generating station (Qasimpur Thermal Power Project), household utensils, river and canal seepage (upper Ganga canal) and dry fall out from the atmosphere are the prime sources of copper. Though copper is essential for metabolic activity, its excess leads to severe mucosal irritation and corrosion, widespread capillary damage, hepatic and renal failure and gastrointestinal irritation. It has been reported that such cases are on the rise which correlates well with the continuously rising level of copper in and around Aligarh. Small amount of zinc is important for plants and animals including human being. But at higher levels it causes a low degree of toxicity, viz., chronic zinc toxicity, in man. Symptoms of zinc toxicity in human include vomiting, dehydration, electrolyte imbalance, abdominal pain, nausea, vertigo, dizziness, and lack of muscular coordination. Acute renal



failure by zinc chlorides has been reported at Aligarh.

The high Zn concentration at Aligarh may be attributed to paint and pigment manufacturing industries, metal alloys, soap and detergent manufacturing industries, municipal water supply, excessive agricultural fertilizer and seepage through upper Ganga canal.

Lead is poisonous in higher concentration. Aligarh has a high concentration of lead. Its sources could be Ganga canal seepage, metals plating industries, paints and pigments manufacturing industries, petrol vehicles, dry land dust fall, domestic and industrial effluents, locks industries using excess lead.

Lead toxicity causes haemoporetic, nervous, renal, cardiovascular and reproductive disorders. Children get maximum exposure due to 'hand to mouth' activity (Pica).

Aligarh has higher levels of Cr. Its toxicity depends on the valence state of Cr,  $\text{Cr}^{3+}$  being the least toxic (Grosman, 1966). Its soluble compounds (sulphates and nitrates) react faster in producing toxic effect (Mazoyer, 1968). High intake of  $\text{Cr}^{6+}$  is reported to cause diagestive tract cancer (Novakova et al., 1974).

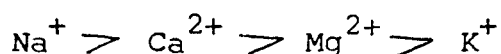
Chromium exposure is reported to cause lung cancer, cutaneous and nasal mucous memberane ulcer and dermatitis and respiratory illness, and are above permissible limits suggested by USEPA, WHO, AWWA, ISI and ICMR.

The cadmium values are not too high and are well within the safe limits at Aligarh.

Lithium is slightly above the safe limits, but its effect is not clearly understood on the human system.

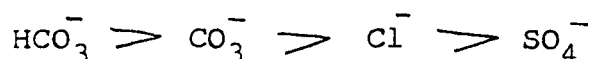
#### 7.9. SOLUBLE IONS, EXCHANGEABLE CATIONS, CATION EXCHANGE CAPACITY, SODIUM-ADSORPTION RATIO, EXCHANGEABLE SODIUM PERCENTAGE AND CLASSIFICATION OF ALIGARH SOILS

Analysis of 'Reh' (saline and alkali) soils for soluble cations and anions were made to determine the composition of the salts present. Samples were analysed for calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride and sulphate. Table-21 shows sodium as the most dominant cation in all the profiles. The concentration of cations in the following order :-



The  $\text{Mg}^{2+}$  is higher on the surface and at depth but less in between. The concentration of soluble potassium also varies in a similar manner.

The concentration of soluble anions are in the following order :-



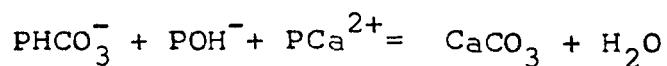
Bicarbonate is the most dominant among the anions.

### 7.9.1. Discussion

Soil represents a heterogeneous, polyodisperse system. The most common exchangeable components being  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{H}^+$ ,  $\text{K}^+$ ,  $\text{Na}^+$  and  $\text{NH}_4^+$ ,  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ ,  $\text{H}_2\text{PO}_4^{2-}$ ,  $\text{HPO}_4^{2-}$ ,  $\text{HCO}_3^-$ . Alkali soils are exceptionally high in  $\text{Na}^+$  and, to some extent, anions of humic acid. The capacity of soils to adsorb and exchange cations and anions greatly depends on clay content, organic matter and mineralogical composition. The atmospheric nature of clays is on account of their capacity to acquire charge from the surrounding soil solution.

But the electric charge and surface charge density vary with pH of the solution. The negative charge grow and the positive charge decreases with rising pH. The property was used in the past to differentiate the soils and, subsequently, in the classification of soils.

As observed by Krauskoff (1967), the kankar zones of Aligarh soils were found where pH was higher. The following reaction holds good when there is a high concentration of bicarbonates :-



At higher pH the reaction proceed towards right with precipitation of calcite and at lower pH dissolution take place. There can be two possible origin of kankar zone in

the soils : (i) primary i.e. inherited from the parent rock, and (ii) secondary, i.e. developed or formed in situ.

It has been established that carbonate in Indo-Gangetic alluvium is of secondary origin, related to depth and ground water table. Earlier, Sehgal and Stoops (1972) and Manchanda (1978) also arrived at similar conclusions.

The concept of sodium adsorption ratio (SAR) was developed to define equilibrium between soluble and exchangeable cations (USDA, 1968). The equation is as follows :-

$$SAR = \frac{Na^+}{\frac{Ca^{2+} + Mg^{2+}}{2}}$$

where  $Na^+$ ,  $Ca^{2+}$ ,  $Mg^{2+}$  are concentrations in saturation extracts in meq/l.

The relationship between exchangeable sodium percentage (ESP) and SAR is as follows :-

$$ESP = \frac{100 (-0.0126 + 0.01475 \times SAR)}{1 + (-0.0126 + 0.01475 \times SAR)}$$

The SAR values of Tappal soils ranged from 108.81 to 135.33 and ESP values ranged from 61.42 to 135.33. They can, thus, be classed as light to heavy (sandy and clayey) in texture and that they are of relatively recent origin. Further, the pH values of all the horizons at Tappal is greater than 8.5 with extremely high exchangeable sodium ( $> 60$ ).

Bicarbonate and carbonates are dominant and chloride and sulphate are low. The unusually high SAR, ESP, pH and CEC values place the soils at Tappal under highly alkaline category.

Certain crops are sensitive to excess sodium and 'bicarbonate toxicity' in soils. The concentration of  $\text{Na}^+$ ,  $\text{HCO}_3^-$  and  $\text{Cl}^-$  depend on the water used for irrigation.

The soils at Jawan have pH up to 8.5, CEC between 10 to 17, electrical conductivity greater than 4 mmhos/cm, SAR greater than 15 and ESP more than 15 with high proportion of sodium cation. They can thus be classified as saline-alkaline soils.

The data obtained for Panjipur profiles gave ESP greater than 50, pH greater than 8.5, sodium as the dominant cation, high bicarbonate and carbonates and low chloride and sulphate. They are thus saline-alkaline soils changing towards sodic soils. This may be owing to factors like poor drainage, permanent water-logging, etc.

In a similar manner soils at Sikandra Rao fall under saline-alkaline category.

The soils at Atrauli and Panhethi, however, are alkaline.

To conclude the soil at Tappal, Panjipur, Atrauli, and Panhethi are highly alkaline while those at Jawan and Sikandra Rao are saline alkaline (Figs. 37 to 42).

## TAPPAL

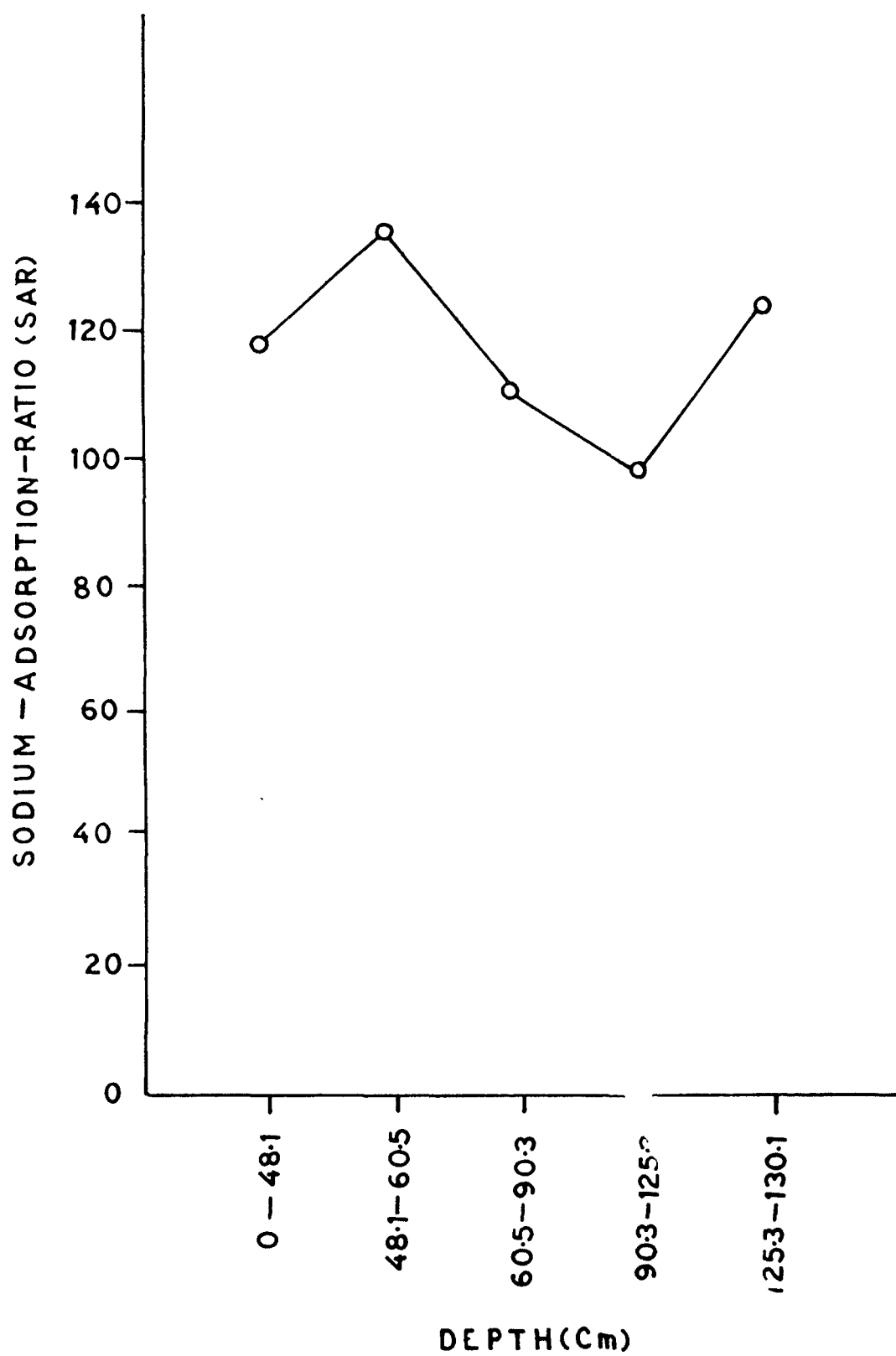


FIG37-VERTICAL VARIATION OF SAR  
IN SOIL PROFILE

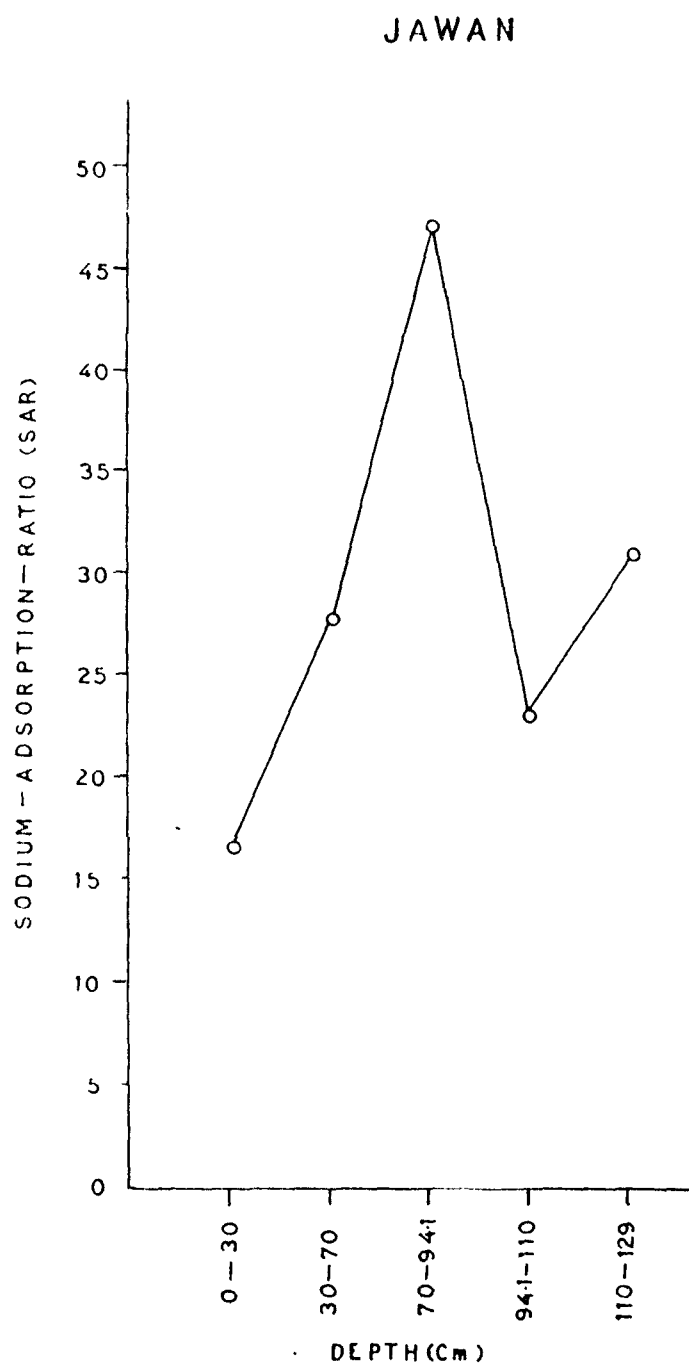


FIG38-VERTICAL VARIATION OF SAR  
IN SOIL PROFILE

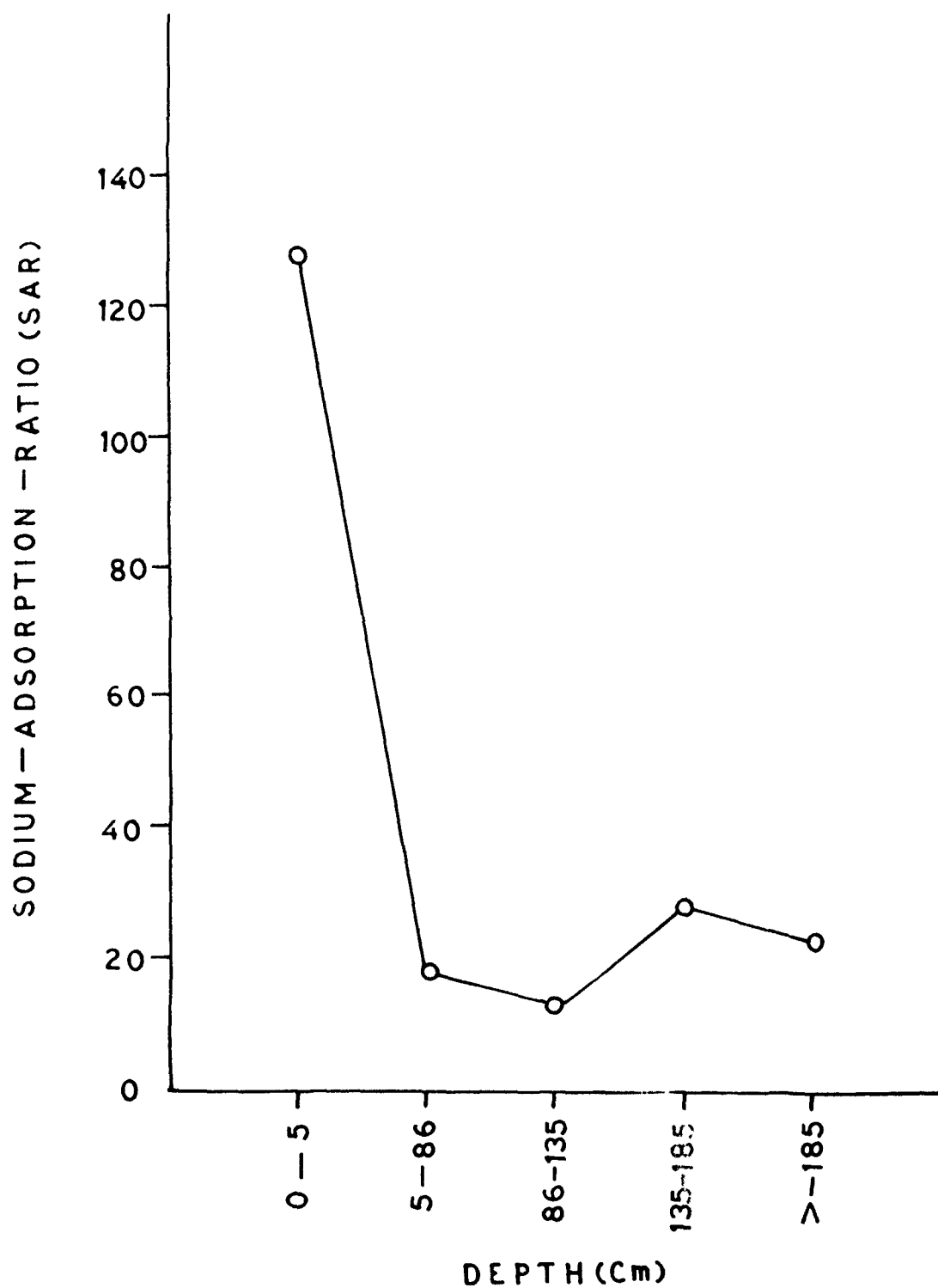


FIG 39 VERTICAL VARIATION OF SAR  
IN SOIL PROFILE



## ATRAULI

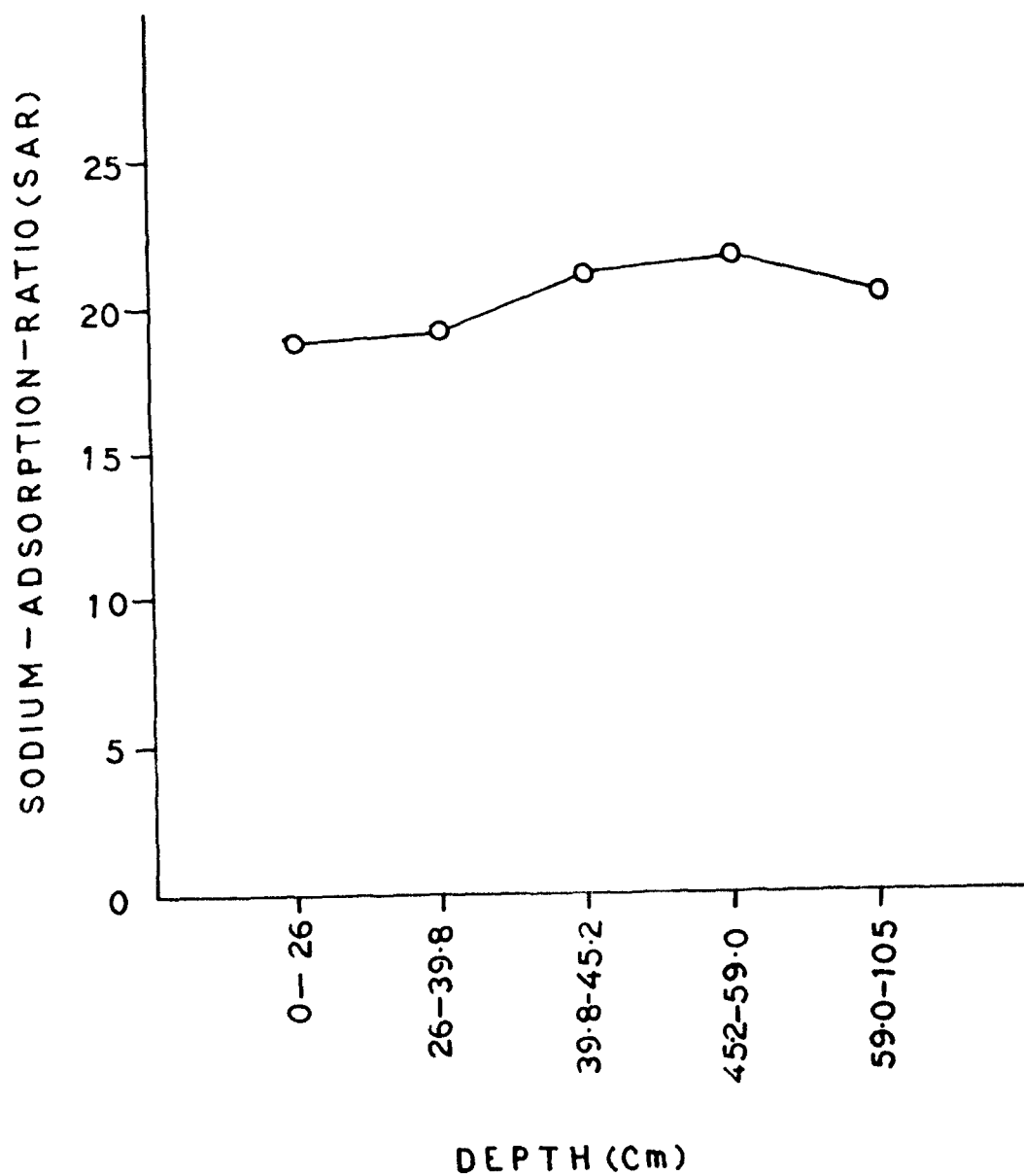


FIG 40-VERTICAL VARIATION OF SAR  
IN SOIL PROFILE

## PANHETHI

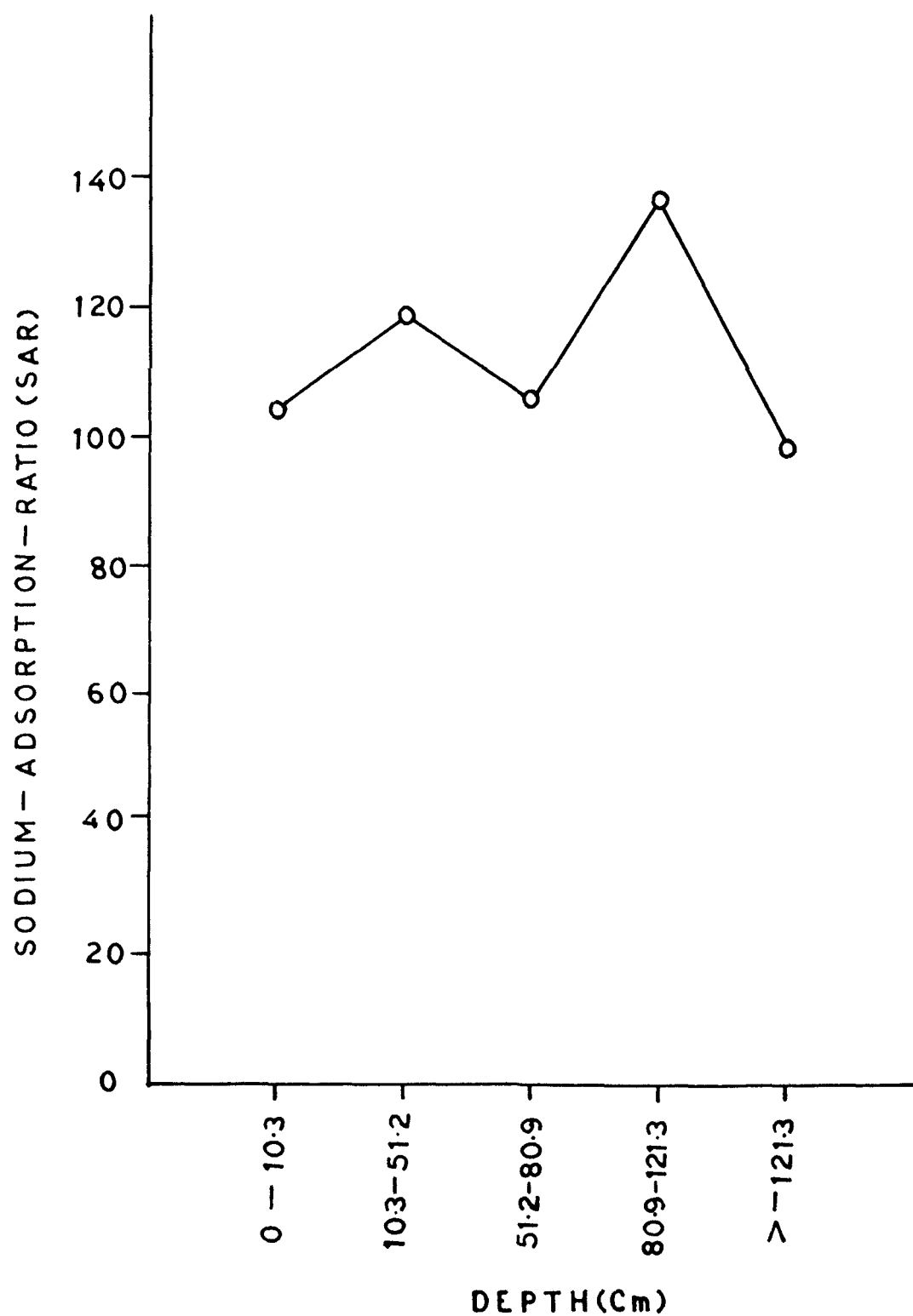


FIG 41-VERTICAL VARIATION OF SAR  
IN SOIL PROFILE

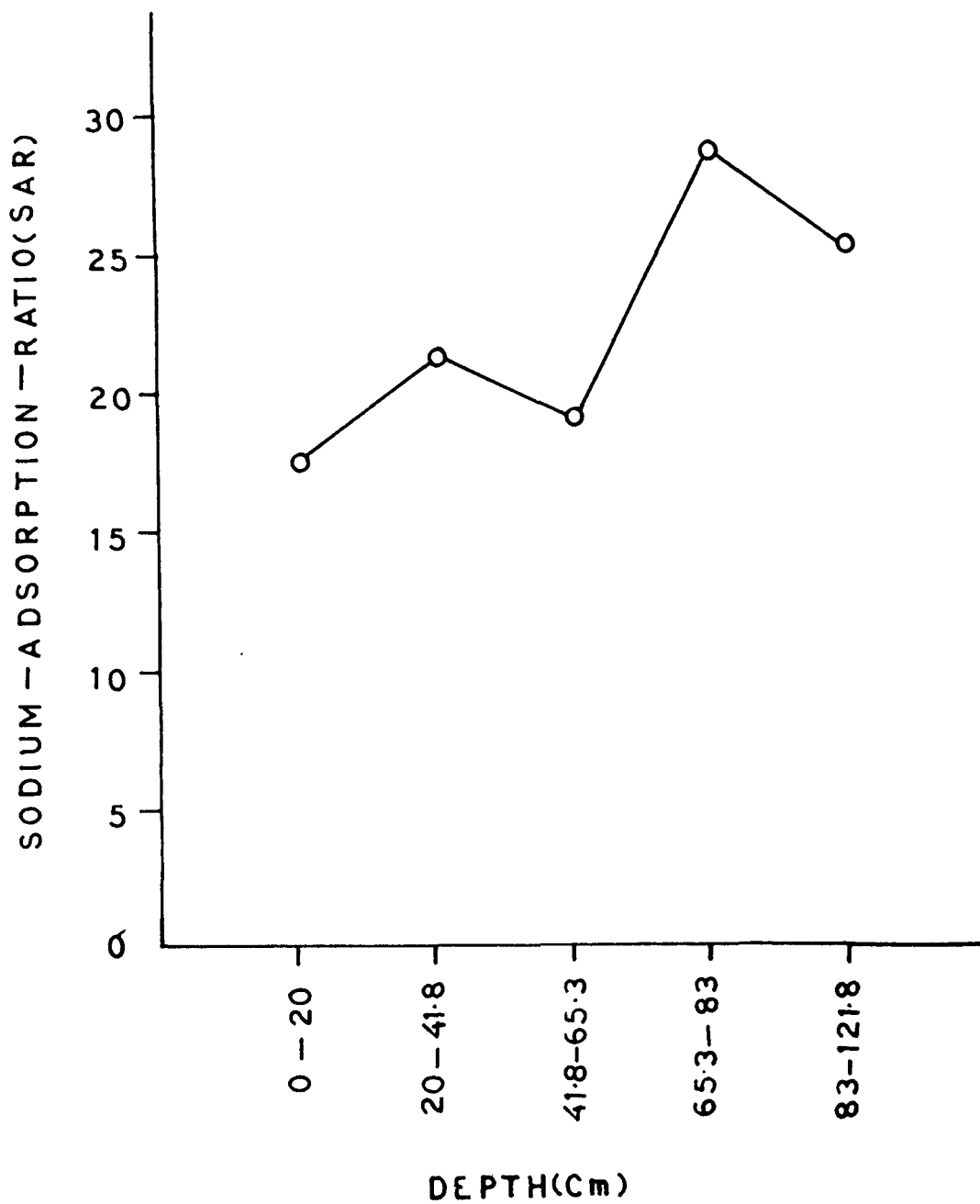


FIG 42-VERTICAL VARIATION OF SAR  
IN SOIL PROFILE

#### 7.10. THE FERTILITY STATUS OF THE SOILS OF ALIGARH

The salinity and alkalinity of soils reduce their fertility and hence the productivity of crop. Aligarh district is one of the worst affected districts of the state of U.P. More than 7 per cent of the total geographic area is saline and another 7000 hectares of land under cultivation is suffering with severe salinity and alkalinity (Map 17).

For understanding the increase in the level of salinity and alkalinity in the fertile soils, the district was divided into seventeen blocks (Table-2 ). Of these fourteen blocks have very low available nitrogen and phosphorus. The Bijauli block has moderately available nitrogen, and Mursan, Sasni, Chandaus have low available phosphorus. The available potassium is high through out the district.

The organic matter and available nitrogen in these soils decreases with increase in pH, salt content and depth (Lawra, 1973; Maliwal, 1975).

The nitrogen cycle can be looked upon as two super-imposed cycles, one involving the soil-plant-soil cycle and atmosphere-microbe-soil-plant cycle.

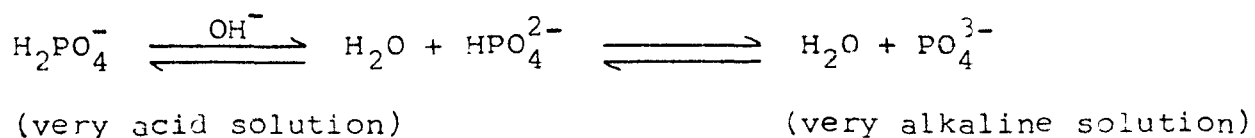
The greatest contribution of nitrogen is by microbial association with higher plant. The best-known are those of the legumes which bear root nodules supporting Rhizobium. But at higher pH ( $>10$ ) rhizobia organism do not survive. (Bhardwaj, 1975; Bhardwaj and Abrol, 1978).

The nitrogen cycle has been altered to a great extent by human activities like drainage of wet lands, use of nitrogenous fertilizers, addition of nitrogen through combustion reactions as in automobiles, waste discharge of lock industries, intensive canal irrigation and accumulation of salts. This calls for minimization of inorganic nitrogen as fertilizers among other measures.

#### Phosphorus

Although phosphorus belongs to the same subgroup as nitrogen in the periodic table of elements, they are strikingly different in their geochemical and geobiological behaviour (Piperrou, 1976).

The content of phosphorus in the soils of Aligarh area is very low which suffers with low availability of phosphorus. This may be due to its triple negative charge (reduced state) and low solubility of most of its salts. Its transport, thus, is slow through the soils. Under alkaline conditions, it tends to form insoluble phosphates or held on the exchange complex tightly. In acid soils, only  $\text{H}_2\text{PO}_4$  ions are present, but as the pH increases, first  $\text{HPO}_4$  and, finally,  $\text{PO}_4^{3-}$  ions dominate. The following equation represents the ionic groups stable under different conditions :-



This explains low level of phosphorus in soils of Aligarh.

### Potassium

The available potassium is high in all the soils of Aligarh. The total quality of this element is generally greater than that of any other major nutrient element. The soils of Aligarh area are rich in illite and vermiculite which act as good K reserve. In the presence of clay minerals, the potassium of illite and vermiculite becomes 'fixed' by the soil clay colloids. The potassium ion as well as ammonium fits in between crystal units of these expanding clays. This potassium is not exchangeable. High pH favours dissolution of K-bearing minerals (feldspars and biotite in the sand and illite in the clays) takes place. Potassium is released more in the presence of NaCl. This accounts for ready availability of potassium.

## CHAPTER - VIII

## CONCLUSION

The alkalinity and salinity in the soils along the Indo-Gangetic tract is rising at an alarming rate and requires urgent remedial measures. This would require a detailed investigation of soils in affected regions from various aspects. Aligarh lies on one of the worst affected belts of Uttar Pradesh, therefore this part of the belt was chosen for detailed study. The following conclusions have been arrived at :-

All the major 'Reh' areas are located in the central low-lands in the vicinity of upper Ganga canal. There is an extensive seepage through this canal into the lands surrounding it (Pl. 11 b). This shows a good coincidence with the distribution of saline-alkaline patches (Map 17).

The immaturity of texture in the soils has been observed in areas where the topography is trough-like. At Tappal the soil is light (sandy) on the surface, and heavy (clayey) at depth. At Jawan, Panjipur, Atrauli, Panhethi and Sikandra Rao, the soils are, generally, silty-clayey. The soil profiles, generally show a kankar horizon at various depths (Fig. 43). These horizons coincide with the moisture front (high water-table) heavily laden with  $\text{HCO}_3^-$  and  $\text{CO}_3^{2-}$  ions.

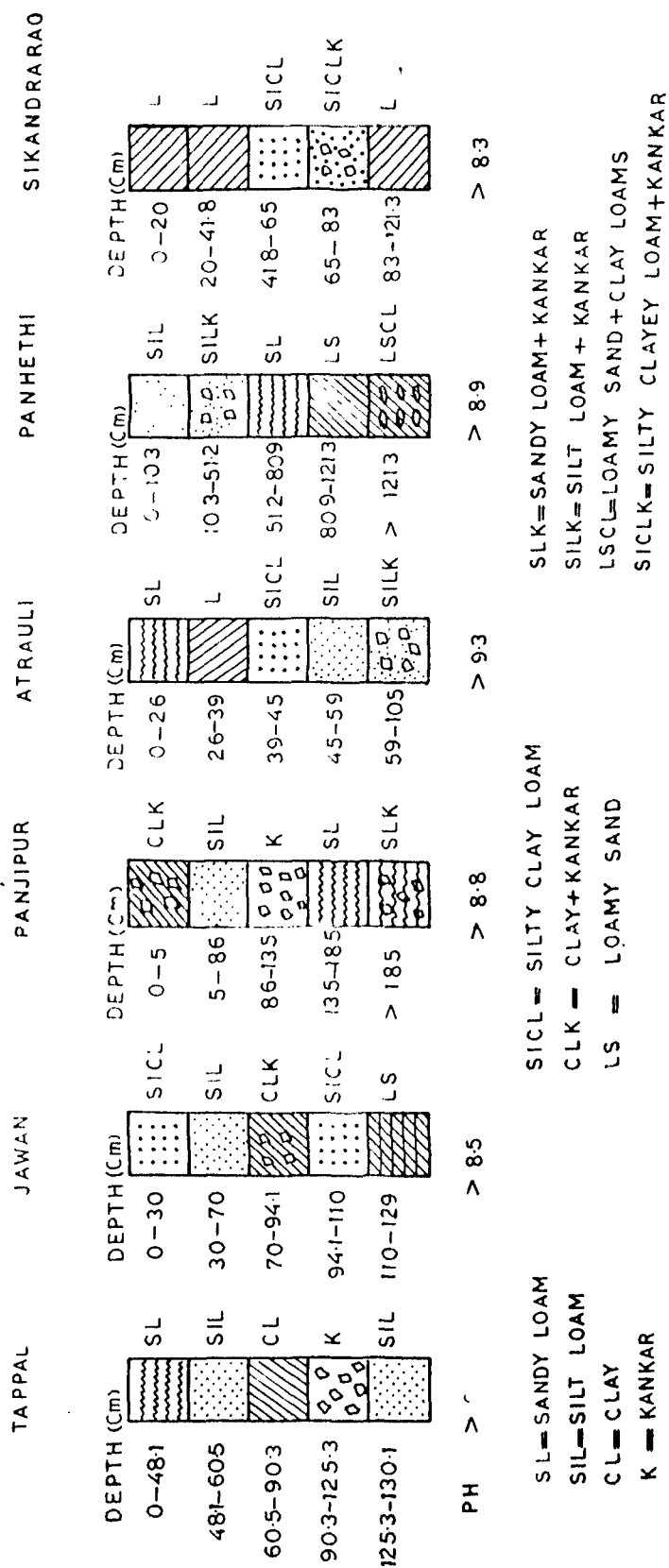


FIG. 43—SOIL PROFILES OF ALIGARH AREAS



Among the most dominant minerals is quartz followed by muscovite. Other light minerals are mostly feldspathic - orthoclase, microcline and plagioclase. The heavy minerals comprise opaques, tourmaline, zircon, garnet, biotite, chlorite, kyanite, hornblende, staurolite, epidote, and rutile.

The mineral assemblage indicates a Himalayan provenance of moderate to high rank metamorphic rocks with some minor igneous and sedimentary rocks. This confirms the conclusion arrived at in other localities in the plain by Wadia (1935), Murthy and Mathur (1964), Roonwal (1967, 1975), Sidhu and Sehgal (1976), and Ghani and Ansari (1984).

The calcite which is a common mineral in the 'Reh' belt passing through Aligarh is authigenic. There is a general scarcity of feldspar which can be due to their break down to clay minerals.

The most dominant clay mineral is illite. The relative abundance of clay minerals in the soils at different localities are as follows :-

Tappal : Illite > chlorite > kaolinite > vermiculite

Jawan : Illite > vermiculite > kaolinite

Panjipur : Illite > vermiculite

Atrauli : Illite > chlorite      kaolinite

Panhethi : Illite > kaolinite

Sikandra Rao : Illite > chlorite

The bulk chemical analyses of the soils give high percentages for  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$ . Among the trace metals, the

concentration of nickel is above the critical limit in the entire belt (Tables-24,25) ranging from 5 to 18 ppm. Similarly, the concentration of Cu too is above the critical limit. The lower and higher values recorded are 4 ppm and 22.3 ppm, respectively. However, the safe limit of Cu concentration given by the FWPCF (1968) and Ayers and Branson (1976) is only up to 5 ppm. The analyses also reveal a high contamination of zinc in these soils (27 ppm to 76 ppm, safe limit up to 10 ppm).

Lead, a highly toxic element, too is found much above the safe limits (11 to 62 ppm, safe limit up to 10 ppm). The concentration of chromium which has a permitted limit up to 1.0 ppm, has the values in the range of 4 ppm to 21 ppm. The concentration of cadmium is less than 1 ppm throughout and is well within the permissible limits. Increase in the level of these elements the presence of sources of contamination of these elements. At Jawan, Qasimpur Thermal Power Station, Central Dairy Farm, and a number of metallic paints and pigments industries emit harmful waste and discharge. At Aligarh, the large number of lock industries discharge untreated waste in large quantity. Moreover, nickel, chromium and other harmful metals are added by the thriving electroplating industries. The wastes are added to and transported by rivers, like Ganga, Yamuna, Kali, Neam, Karon, Sengar, through irrigation and through the Upper Ganga Canal which passes through the central lowlands. The rivers carry heavy pollutional metallic contaminations from Delhi and other cities downstream.

The chemical characteristics vary, like, ESP from 18.64 to 66.79, SAR 16.39 to 137.17, pH 8.1 to 10.97, EC 0.13 to 14.60 mmhos/cm. Thus both saline-alkaline and alkali soils are indicated. The chloride and bicarbonate of sodium are the dominant salts but carbonate and sulphate are relative in lesser amount. There is a tendency of advancing alkalinity in these soils.

The dominance of  $\text{CO}_3^-$  and  $\text{HCO}_3^-$  of  $\text{Na}^+$  place soils of Jawar and Sikandra Rao in the alkaline or sodic category instead of saline-alkaline as suggested by earlier workers. The soils of Aligarh are, in general, sandy to silty and clayey. Imperfect drainage and closeness of ground water level to the surface causes widespread salt efflorescence, especially, during the summer months. The concentration of  $\text{NaHCO}_3$  too goes up.

Along the Upper Ganga canal, the underlying 'kankar' beds get cemented so hard that percolation of water is almost zero, causing stagnation of water at the surface resulting in a high degree of turbidity. On evaporation, flakes of clays are formed on the surface rendering the soils completely barren. Only the salt tolerant grasses can grow during the rainy season. Thus the main causes which accelerate 'Reh' formation at Aligarh are water-logging, clay deposition, trough-like topography and arid condition. The top layers get leached as a result of which the processes of salinization and alkalization proceed very

fast. The high concentration of sodium in these soils, as indicated by their pH (8.7 to 10.97) is obtained from the breakdown of plagioclase feldspars through hydrolytic dissolution and carbonation. This creates a potential sodium hazard. It is established that at 25°C, bicarbonates of alkali as well as alkaline earth metals transform into calcite (Kovda, 1964).

The quality of ground water at Aligarh, specially at Tappal and Central lowlands, is very poor and saline.

The presence of illite, vermiculite and micas impart the properties of swelling, shrinking cohesion and plastered look to these soils. Shrinkage produces irregular, checkered, polygonal and trapezium-shaped cracks due to highly flocculated clays, like, illite, vermiculite and kaolinite and also the formation and spontaneous dehydration of gel-like material under aqueous environment (Pl. 12). A close examination of these cracks under SEM reveal a radiating pattern of salt crystals on the surface (see Pl. 9 a & b). These can be explained by the capillary action during dehydration at the top.

The physical-chemical barrier created by kankar zone causes accumulation of Cr, Mn, Fe, Co, Ni, Zn, Cd, Pb, Li and other elements brought in from various sources and through wastes.

The poor availability of plant nutrients (nitrogen, phosphorus, potassium) in the soils of Aligarh is due to

PLATE 12

Photograph showing development of mudcracks in Tappal soil of Aligarh district. Since mudcracks are characteristic of soils with high proportion of kaolinite and illite/chlorite. Note white encrustation of 'reh'.



PLATE · 12

non-survival of nitrogen-fixing bacteria under high pH, high sodium percentage and salt content.

Thus, in conclusion, a combination of factors geological, climatic and hydrological are involved in the formation of 'Reh' soils in Aligarh and other areas around it.

Among the geologic factor, weathering of the Himalayan rocks is the primary source of minerals and soluble salts. Sodium carbonate and calcite are formed through base exchange and release of sodium. Among the climatic factors, rainfall plays greater role than the temperature, in the transportation and accumulation of soluble salts in Aligarh and other parts of Indo-Gangetic alluvium. The main hydrological factors is the salinity of water, closeness of water-table to the surface (2 m depth) and capillary conductivity during hot seasons.

Secondary salinization is another cause for rise in the level of salinity and alkalinity. The agents for secondary salinization are uncontrolled economic activities, rise in water table and removal of natural covers due to over grazing. In Aligarh, plant covers greatly influence soil salt regimes. Absence of thick cover of herbaceous plants increases evaporation of ground water, thereby, increasing the accumulation of salt manifold. In a study conducted by U.P. Usar Land Reclamation Committee (1939), it was reported that of the 20 selected districts, grazing incidence varied from ten to seventeen animals per hectare with an average of 13.7 for all animals

or ten bovine cattle per hectare. Thus the phenomena of salt accumulation is related to unchecked destruction of natural vegetation. It has already been suggested that intensive canal irrigation and extensive seepage of water from upper Ganga Canal are among the main reasons for salt accumulation. It is estimated that 40 to 50 hectare-cm of water is being added annually to the ground water by a single irrigated crop. This can well be observed at Tappal where during the rainy season water table rises to the surface and water starts flowing on it.

#### SUGGESTIONS FOR ENHANCEMENT OF SOILS OF ALIGARH AND THE SURROUNDING AREA

The main natural resource in Aligarh area is agriculture. The main method of reclamation of saline soils is through establishment of drainage and resorting to leaching through excessive irrigation with good quality water. This measure became inadequate as there is need for a ready source of soluble calcium to neutralize the alkali, to replace exchangeable sodium in the soils and to flocculate clay for improving permeability. The following methods are suggested for reclamation and improvement of the large tracts of saline and alkaline soils of Aligarh area :-

- (i) physical and hydro-technical method
- (ii) biological method and
- (iii) chemical method.



### (i) Physical and Hydro-technical Method

Deep ploughing, sub-soiling, sand filling and profile inversion improve water infiltration. Opening of the land and breaking up the hard encrusted surface soil, with or without upturning the sub-soil, is only possible through mechanical means. Sub-soil breaking of hard kankar pans, clay pans, or compact cemented sub-soil layer requires use of chisels drawn by powerful tractors reach the pan lying 40 to 100 cm below the surface. The sand filling or 'sanding' will improve water and air permeability allowing excess soluble salts to be washed down to the root zone through leaching.

Temporary measures, like flooding the fields with water, transfers salts to lower level. This methods has lead to failure of many reclamation projects in India and abroad. Another measure could be to properly level the field and divide it into small plots, breaking hard pans by cater pillers with the help of heavy tractors and irrigation with good quality water. Rotation of paddy and rice crops should be resorted to.

### (ii) Biological Method

The application of cattle manure for treatment of saline and alkaline soils, liberation of carbon dioxide and organic acids which help dissolve soluble calcium salts in the soils

and also neutralization of alkalis. The decomposition of organic matter improves soil permeability and increases water-stable aggregates. This is brought about by a complex series of polysaccharides synthesized by bacteria flourishing in the decomposing organic matter, and by their products which act as soil binding material.

The use of farmyard manure compare, favourably with gypsum and lowers pH (Bhumbla, 1972). The use of sugar factory molasses and pressmud for the reclamation of saline and alkaline soils have also been successfully applied. Dhar (1939) has recommended addition of 12.5 tonnes of molasses plus 12.5 tonnes of press mud per hectare to highly alkaline soils for complete reclamation. This is recommended three to four weeks before the paddy sowing time, followed by flooding, ploughing and transplanting. The sesbania green manure crop in combination with gypsum should be applied for a number of years. Sulphurated hydrogen is generated by decomposition which serves as a strong acid for neutralizing alkali soils and increases their hydraulic conductivity and allows sodium to go through leachates.

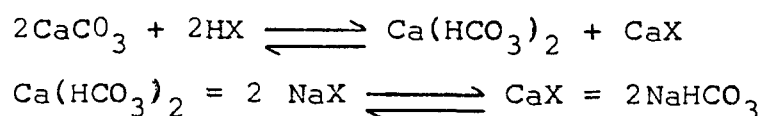
Growing of salt resistant grasses, like, khar usar (sporobolus arabicus), bhurbhumi (sporobolus coromandelianus), dab (eragrostis cynosuroidis), dub (cynodan dactylon) have also proved helpful. Eucalyptus hybrid trees are also highly salt tolerant and help lower both pH and ground water level thereby reducing alkalinity problem.

Growth of nitrogen fixing bacterias should be encouraged by planting leguminous plants and blue green algae.

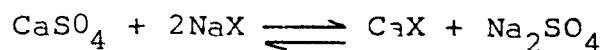
### (iii) Chemical Methods

Gypsum, limestone and sulphuric acid have been used in the reclamation of extremely alkaline soils. Gypsum, being the cheapest source of soluble calcium, are applied for replace exchangeable sodium and grounded limestone is satisfactory for sodic soils. If the sodic soils contain lime than acidulating material such as sulphuric acid should be applied through irrigation water. This increases the rate of filteration. The reclamation involves the following :-

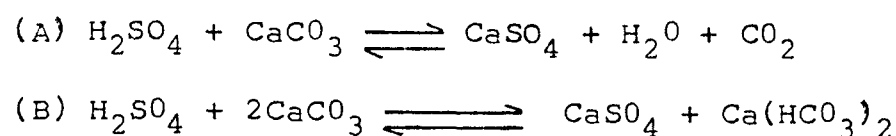
#### 1. Limestone on sodic soils



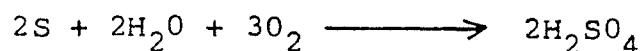
#### 2. Gypsum



#### 3. Sulphuric acid



#### 4. Sulphur



Biological oxidation to sulphuric acid is the first step.

There is need to make intelligent use of water as indiscriminate introduction of canal irrigation may cause excessive seepage, rise in water-table, widespread water-logging and increase in salinity. The unplanned irrigated agriculture, instead of heralding prosperity and economic stability may threaten the very security of the land. The problem of salinity poses a challenge to irrigated agriculture. The success depends on how effectively do we take up that challenge and save our national heritage, the soil, from deterioration.

#### ECONOMIC EXPLOITATION OF REH

Instead of resorting to temporary reclamative measures, reh itself can be used to manufacture sodium bicarbonates, carbonate and sodium sulphate. The bulk of sodium carbonate can profitably be used in making paper pulp by employing Kraft process. Also as ionizable bulking agent, they can be used for making synthetic detergent powder 'soap' for household use. It can also be used in other industries, like heavy chemicals, ceramics, glass and textile.

On socio-economic level, exploitation of sodium bicarbonate, carbonate or sodium sulphate from reh weighs much heavier than the agricultural produce. Moreover, appropriate exploitation of reh will also generate jobs on a sizeable scale. The curse of reh or usar can thus be converted into a boon.

# REFERENCES

- Agarwal, R.R.; and Mehrotra, C.L., 1951, Soil survey and soil work in U.P., Allahabad, I, pp. 7.
- Agarwal, R.R., Yadav, J.S.P., and Gupta, R.N., 1968, Saline and soils of India, I.C.A.R., New Delhi, 285 p.
- Amani, K.Z., 1976, Agricultural land use in Aligarh district, pp. 13.
- Auden, J.B., Gupta, B.C., Roy, P.C. and Hussain, M., 1942, Report on sodium salts in Reh soils in the United Province, with notes on occurrence in other parts of India. Prof. Paper G.S.I., 77, 1, pp. 1-45.
- Awasthi, S.C., 1981, Problem of Salt efflorescent and its economic exploitatin in Punjab, Rec. G.S.I., 112, pp. 90-91.
- Azad, A.S., Sekhon, G.S. and Arora, B.R., 1986, Distribution of cadmium nickel and cobalt in sewage water irrigated soils, Jour. Ind. Soc. Soil Sci., 34, pp. 619-621.
- Bailey, S.W., , The status of clay mineral structures. Proceed.14th Nat. Conf. on clays and clay minerals, pp. 1-4.
- Bateman, R.M. and Harpenden, J.A., Catt, 1985, Modification of heavy mineral assemblages in English conversands by acid pedocnemical weathering. Jour. Catena, 12, pp. 1-21.
- Baumgardner, M.F., Kristof, S.J., Johansen, C.J. and Zachary, A.L., 1980, Effect of organic matters on multispectral properties of soils. Proc. Indiana Acad. Sci., 79, pp. 413-422.

- Bear, F.E., 1964, Chemistry of the soil. Oxford and IBJ Publishing Co., New Delhi, 515 p.
- Bhumbla, D.R., 1977, Alkali and saline soils of India. Proceed. Indo-Hungarian Seminar, Management of Salt Affected soils, pp. 14-20.
- Bohor, B.F. and Hughes, R.E., 1971, Scanning Electron Microscopy (SEM) of clays and clay minerals. Clays and Clay Minerals, 19, 1, pp. 49-54.
- Boyko, Hugo, 1966, Salinity and Aridity. Dr. Junk Publishers, The Hague, Netherlands, 407 p.
- Bradley, W.F. and Weaver, C.E., 1956, A regularly interstratified chlorite-vermiculite clay minerals. Am. Mineralogist, 41, pp. 497-504.
- Bresler, E., McNeal, B.L., Carter, D.L., 1982, Saline and sodic soils. Springer-Verlag, Berlin Heidelberg, New York, 236 p.
- Brown, G., 1961, The X-ray identification and crystal structures of clay minerals. Min. Soc. (clay minerals group), London, 544 p.
- Buckman, H.O., and Brady, N.C., 1980, The nature and properties of soils. 8th edition, Eurasia Publishing House (Pvt. Ltd.), New Delhi, 592 p.
- Burrard, S.G., 1912, On the origin of the Himalayan mountains, Prof. Paper G.S.I., 12, Calcutta, pp. 11.
- Carroll Dorothy, 1970, Clay minerals, A guide to their X-ray identification. The Geol. Soc. Amer., 75 p.

- Centre, W., 1880, Note on Reh or alkali soils and saline well.  
Rec. G.S.I., 13, pt. 2, pp. 221-289.
- Charlotte, M. and Warshaw, 1958, Experimental studies of Illites,  
Proceed. of 7th Nat. Cont. on clays and clay minerals, pp.  
303-316.
- Chaturvedi, A.K. and Ramahshay, B.C., 1981, Ground water chemistry  
and formations of carbonate concretions in alluvial soils.  
Jour. Geol. Soc. of India, 22, 7, pp. 331-335.
- Cowie, H.M., 1921, Criticism of R.D. Oldham's paper on the  
structure of Himalayas and the Gangetic Plain as elucidated  
by the Geodetic observations in India. Mem. G.S.I., Prof.  
Paper 18, Dehra Dun, pp. 26.
- Daniels, R.B. and Gamble, E.E., 1978, Relations between  
stratigraphy, geomorphology and soils in coastal plain  
areas of south-eastern U.S.A., Geoderma, 21, pp. 41-65.
- Das, S.C., 1956, An X-ray investigation of the mineralogical  
composition of some soil clays. Jour. Ind. Soc. Soil Sci.,  
4, pp. 135-138.
- Deer, W.A., Howie, R.A., Zussman, J., 1966, An introduction to  
the Rock forming minerals. ELBS and Longman, London, 528 p.
- De Sigmond, A.A.J., 1927, Classification of alkaline and salty  
soils. Ist Int. Congr. Soil Sci., Proceed. 1, pp. 330-344.
- Dokuchaev, V.V. 1898, In : Derivation of state factor equations  
of soil and ecosystems. Jenny, H. (1961). Soil Sci. Soc.  
Amer. Proc., 25, pp. 385-388.

- Dubey, D.D., Bangar, K.S., and Sharma, O.P., 1986, Characteristic and classification of some salt affected soils. Jour. Ind. Soc. Soil Sci., 34, pp. 889-892.
- Eades, J.L. and Grim, R.E., 1964, The nature of Illite. Proceed. 13th Nat. Conf. on clays and clay minerals, pp. 33-48.
- Eswaran, H., 1971, Proc. Soil Sci. Soc., Amer., 35, pp. 387-390, in Bull. Mineralogy of Soil clays and clay minerals, Indian Soc. Soil Sci., New Delhi, 1974, pp. 36-64.
- FAO, 1966, Guidelines for soil profile Description. Rome.
- Fitzpatrick, E.A., 1984, Micromorphology of soils, Chapman and Hall, London, New York, 433 p.
- Fortescue, John A.C., 1980, Environmental Geochemistry. A Holistic Approach, Springer-Verlag, New York, U.S.A., pp. 123-130.
- Gansser, A., 1964, Geology of Himalayas (Kumaon Himalayas), Inter-Science Publisher, (John Willey and Sons Ltd., London), pp. 83.
- Garalapuri, V.N., 1978, Quaternary geomorphology and aridity in Haryana. Int. Symp. Aridzone Res. and Dev., CAZRI, Jodhpur (Abstract).
- Garrels, R.M. and Christ, CL.L., 1965, Solutions minerals and equilibrium, Harper and Row, New York, 450 p.
- Gawande, S.P., Joshi, O.P. and Singh, P., 1980, The genesis and classification of saline-sodic soils of the Bewar distributary command area in the Etah district, Uttar Pradesh, India. Int. Symp. Salt affected soils. CSSRI, Karnal, pp. 102-109.



- Geno, Kirk, R. and Chafetz Henery, S., 1982, Petrology of quarternary fluvial low-magnesian calcite coated grains from Central Texas. Jour. Sed. Pet., 52, 3, pp. 833-842.
- Ghani, N. and Ansari, Mohd. Ajmal, 1984, Minerals and their contribution to soils of Aligarh district, Abstract, National Conference on Pollutational Stress in major Indian River Basins, A.M.U., Aligarh.
- Ghosh, B., Pandey, S. and Singh, S., 1966, Studies in photogrammetry, geomorphic studies of Sojat from aerial photographs to delineate landforms. Jour. Ind. Soc. Soil Sci., 14, pp. 9-12.
- Gile, L.H., Peterson, F.F. and Grossman, R.B., 1965, The K-horizon, A master soil horizon of carbonate accumulation. Soil Sci., 99, pp. 74-82.
- \_\_\_\_\_, 1966, Morphology and genetic sequences of carbonate accumulation in desert soils. Soil Sci., 101, pp. 347-360.
- Glennie, E.A., 1932, Gravity anomalies and the structure of the Earth's crust, Mem. G.S.I., Prof. Paper 27, Dehra Dun pp. 22.
- Glinka, K.D., 1927, The great soil groups of the world and their development. Edwards, Ann, Arbor. Mich.
- Govindarajan, S.V. and Godse, N.G., 1972, Microgeomorphic units as a factor in the formation of soils of Anupgarh tehsil in western Rajasthan and their classification. Indian Jour. Agri. Sci., 42, pp. 860-866.

- Gupta, A.P., Antil, R.S. and Gupta, V.K., 1986, Effect of pressmud and zinc on the yield and uptake of zinc and nitrogen by Corn. Jour. Ind. Soc. Soil Sci., 34, pp. 810-814.
- Gupta, G.N., Gupta, J.P. and Murthy, K.N.K., 1986, Water Retention and Transmission characteristics of some Aridisols. Jour. Ind. Soc. Soil Sci., 34, pp. 169-172.
- Gupta, R.D., Bhardwaj, K.K.R., Marwah, B.C. and Tripathi, B.R., 1986, Occurrence of phosphate dissolving bacteria in some soils of northwest Himalayas under varying Bio-sequence and climosequence. Jour. Ind. Soc. Soil Sci., 34, pp. 498-504.
- Gupta, R.D., Jha, K.K. and Shahi, B.P., 1986, Clay Mineralogy of some soil profiles of Jammu and Kashmir state. Jour. Ind. Soc. Soil. Sci., 34, pp. 577-584.
- Gupta, R.K., Bhumbra, D.A. and Abrol, I.P., 1985, Release of exchangeable sodium from an alkali soil upon Amendment Application Role of variable charge and exchangeable cation. Jour. Soil Sci., 139, 4, pp. 312-317.
- Gupta, R.K., Singh, C.P., and Abrol, I.P., 1985, Determining cation exchange capacity and exchangeable sodium in alkali soils. Soil Sci., 139, no. 4, pp. 326.
- Gupta, R.N., 1968, Clay mineralogy of the Indian genetic alluvium of Uttar Pradesh. Jour. Ind. Soc. Soil Sci., 16, pp. 115-127.

- Gupta, S.K., 1986, Sampling alkali soils and analysis based on spatial variations in unreclaimed and claimed lands. Jour. Ind. Soc. Soil Sci., 34, pp. 839-843.
- Hashmi, S.N.I., 1984, Impact of reclamation of saline and alkali lands on the rural development of Aligarh district, M.Phil. dissertation, A.M.U., Aligarh.
- Henin, S., Robichet, O. and du Rouchet, M.J., 1953, Experimental weathering of a schist-comparison with a granite. C.R. Acad. Sci., Paris 273, pp. 1437-1439.
- Hicks, R., Schenken, J.R. and Steinrauf, M. Ann, 1974, Laboratory instruments, Harper and Row Publishers, London, 224 p.
- Hilgard, E.W., 1906, Soils. The Macmillan Co., New York, 593 p.
- \_\_\_\_\_, 1910, Soils.- their formation, properties, composition and relation to climate and plant growth in humid and arid regions, New York.
- Hilwig, F.W. and Karale, R.L., 1973, Physiographic systems and elements of photo-interpretation as applied to Soil Survey in Ganges plain, Jour. Ind. Soc. Soil Sci., 21, pp. 205-212.
- Holland, T.H. and Christie, W.A.K., 1909, Origin of the salt deposits of Rajputana, Rec. G.S.I., 38, pp. 154-186.
- Hutchison, C.S., 1973, Laboratory Handbook of Petrographic Techniques. Wiley-Interscience Pub., New York, 527 p.
- Hutton, J.T., Norish, K., 1974, Silicon content of wheat husks in relation to water transpired. Aust. Jour. Agri. Res., 25, pp. 203-212.

- Jackson, M.L., 1958, Soil chemical analysis, Constable and Co. Ltd., London, 498 p.
- \_\_\_\_\_, 1968, Weathering of primary and secondary minerals in soils. Trans. 9th Int. Cong. Soil Sci., 4, pp. 281-291.
- Jenny, H., 1941, Factors of Soil Formation, McGraw Hill, New York and London.
- Joffe, C.S., 1936, Pedology, Rutgers Univ. Press, New Brunswick, New Jersey.
- \_\_\_\_\_, 1949, Pedology, Pedology Publication, Brunswick, New Jersey.
- Jongerius, A., 1964, Soil Micromorphology. Proceed. of second Int. Working meeting on Soil Micromorphology. Elsevier Pub. Co., New York, 540 p.
- Joshi, D.C., 1986, Potassium Release Behaviour in some arid soils. Jour. Ind. Soc. Soil Sci., 34, pp. 56-63.
- Joshi, O.P., Khan Hameed, H., Biddappa, C.C. and Manikandan, P., 1986, Transformation of slow release nitrogenous fertilizer in red sandy loam soil. Jour. Ind. Soc. Soil Sci., 34, pp. 600-602.
- Kanwar, J.S., 1959, Two dominant clay minerals in Punjab soils. Jour. Ind. Soc. Soil Sci., 7, pp. 249-254.
- \_\_\_\_\_, 1961, Clay minerals in saline-alkali soils of Punjab. Jour. Ind. Soc. Soil Sci., 9, pp. 35-40.
- Kanwar, J.S. and Sehgal, J.L., 1962, Classification of saline-sodic and normal soils of Karnal district. Jour. Ind. Soil Sci., 10, pp. 19-25.

- Kanwar, J.S., 1962, Reclamation of saline alkali soils. Proc. Symp. Salinity and alkalinity. I.A.R.I., New Delhi.
- Karale, R.L., Tamhane, R.V. and Das, S.C., 1969. Soil genesis as related to parent material and climate. Jour. Ind. Soc. Soil Sci., 17, pp. 227-239.
- Kaswala, R.R. and Deshpande, S.B., 1986, Silt and clay mineralogy of black alluvial soils of south Gujarat. Jour. Ind. Soc. Soil Sci., 34, pp. 160-168.
- Kaushik, R.N. and Shukla, U.C., 1977, A study on the development of salt affected soils in a typical area. Jour. Ind. Soc. Soil Sci., 25, pp. 276-283.
- Khan, S. and Singhal, J.P., 1966, Clay mineralogical studies on Aligarh soils. Proceed. N. Acad. Sci, India, XXXVI, IV, pp. 889-892.
- Khanna, S.S., Ahuja, R.L., Manchanda, M.L., Sangwan, B.S. and Goyal, V.P., 1977, Soil-landscape relationships of the dune-infected Precambrian pedepain area in south-western part of Haryana. Annals of Arid zone, 16, pp. 201-212.
- Khera, A.P., 1964, Development of 'kankar' in saline and alkali soils of Delhi state, M.Sc. thesis, IARI, New Delhi.
- Kovda, V.A., 1961, Principles of the theory and practice of reclamation and utilization of saline soils in the arid zones. Proc. Tehran Symp., UNESCO.
- \_\_\_\_\_, 1964, Alkaline soda-saline soils. Proc. Symp., Sodis Soils, Budapest *Aejrokemia es Talajtan*, 14, pp. 15-48 (supplementum).

- Krishnan, M.S., 1960, Geology of India and Burma, Madras, 573 p.
- \_\_\_\_\_, 1960, Geology of India and Burma, Madras, 573 p.
- \_\_\_\_\_, 1968, Geology of India and Burma, Madras, 523 p.
- \_\_\_\_\_, 1982, Geology of India and Burma, New Delhi, 510 p.
- \_\_\_\_\_, 1982, Geology of India and Burma, New Delhi, 511 p.
- \_\_\_\_\_, 1982, Geology of India and Burma, New Delhi, 512 p.
- Kuhad, M.S., 1973, Characterization and classification of soils of different bioclimatic regions of Haryana.
- Lauchli, A. and Bielecki, 1983, Inorganic plant nutrition. Encyclopedia of plant physiology. New Series 15 A, Springer-Verlag, Heidelberg, 450 p.
- Leather, J.W., 1914, Investigations on Usar land in the United Provinces, Allahabad, pp. 88.
- Leeder, M.R., 1975, Pedogenic carbonates and flood sediment accretion rates, a quantitative model for alluvial arid zone lithofacies. Geol. Mag., 112, 3, pp. 257-270.
- Lougheed, E.C. Murr, D.P., Miller, S.R., 1979, Effect of calcium and daminozide on ethylene production and softening of apple fruits experimenta, 35, pp. 43-45.
- Maclean, A.H., and Pawluk, S., 1975, Soil genesis in relation to ground water and soil moisture regimes near Vegreville Alberta, Jour. Soil Sci., 26, pp. 278-293.
- Mahrer, Y. and Avissar, R., 1985, A numerical study of the effects of soil surface shape upon the soil temperature and moisture regimes. Soil Science, 139, no. 6, pp. 483-490.

- Manchanda, M.L., 1978, Pedogenic characterization of Satt-impregnated soils of apart of Haryana. Dissertation, Ph.D., HAU, Hissar.
- Manchanda, M.L. and Khanna, S.S., 1979, Soil Salinity and Landscape relationship in part of Haryana, India, communicated to Jour. Ind. Soc. Soil, Sci.
- Martini, J.A., Allocation of cation exchange capacity to soil fraction in seven surface soils from Panama and the application of a cation exchange factor as a weathering index, Soil Sci., 109, pp. 324-331.
- McKeague, J.A. and St. Arnuad, R.J., 1969, Elluviation - elluviation in soils during the quarterternary soil sci., 107, pp. 428-434.
- McKenzie, R.M., 1972, The manganese oxides in soil - A review, Zutschrift fur Pflanzenernabrung and Bodenkunote, 131, Bund Heft, 5, pp.221-242, In, Ve Prakas et al., 1974 Soil Sci. Soc. Amer. Proc., 38, 497 pp.
- Mishra, B. and Khanna, P.K., 1986, Mobility and Transformation of Fertilizer Phosphorus in a Forest soil. Jour. Ind. Soc. Soil Sci., 1, 34, pp. 743-748.
- Misra, R.C., 1981, Geological evolution of Uttar Pradesh, Ninth Birbal Sahni Memorial Lecture, Lucknow, pp. 9-10.
- Mukherjee, S.K., Das, S.C. and Raman, K.V., 1971, Review of soil research in India. Jour. Ind. Soc. Soil Sci., New Delhi.

- Mukherjee, S.K., Biswas, T.D., 1974, Bull. 9, Indian Soc. Soil Sci., New Delhi, 262 p.
- Murthy, R.S. and Mathur, B.S., 1964, special formations of some alluvial soil profiles of the Ganga river plain of central Uttar Pradesh - their origin, development and significance. Bull. Nat. Inst. Sci., India, 26, pp. 110-116.
- Murthy, R.S. and Pandey, S.P., 1978, Land resources of Indus basin, Geology, soils and Landuse. Proc. Nat. Symp. Land and Water Management in the Indus basin (India). PAU, Ludhiana, I, pp. 269-275.
- Nevill, H.R., 1926, Aligarh in a Gazetteer being volume VI of the District Gazetteers of United Provinces of Agra and Oudh, pp. 1.
- Oldham, R.D., 1917, The structure of the Himalayas and Gangetic Plain. Mem. Geol. Surv. Ind., 17, II.
- Paratenova and Yarilova, 1968, Mineralogical Investigations In soil sciences, Universal Book Dept., Lucknow.
- Pathak, S.R. and Patel, N.K., 1980, Study of some physico-chemical characteristics of salt affected soils of Kaira district, Gujarat state. Jour. Ind. Soc. Soil Sci., 28, pp. 31-37.
- Pettijohn, E.J., 1975, Sedimentary Rock, 3 ed., Harper Int., Lond, pp. 122-123.
- \_\_\_\_\_, 1941, Resistance of heavy minerals und geologie age, J. Geol., 49, pp. 610-625.



- Piper, C.S., 1950, Soil and Plant Analysis, Univ., Adelaid, Australia.
- Polynov, B.B., 1937, Cycle of weathering, Murby and Co., London.
- Prasad, J. and Ram, H., 1986, Effect of zinc and copper and Rhizobium Inoculation on phosphorus availability and uptake in Mungbean, Jour. Ind. Soc. Soil Sci., 34, pp. 762-766.
- Prasad, K.K., Karale, R.L. and Biswas, T.D., 1977, Studies on soil genesis from complex geological rocks in an area around Junagarh, Jour. Ind. Soc. Soil Sci., 25, pp. 207-230.
- Pundeer, G.S., Singh, M. and Randhawa, N.S., 1974, Mineralogy of the sand fraction of some flood plain soils of Hoshiarpur district, Punjab, Jour. Ind. Soc. Soil Sci., 22, pp. 269-274.
- Pundeer, G.S., Sidhu, P.S. and Hall, G.F., 1978, Mineralogy of soils developed on two geomorphic surfaces of the Sutlej alluvium in the Central Punjab. Jour. Ind. Soc. Soil Sci., 26, 151 p.
- Puri, A.N., 1949, Soils, their physics and chemistry. Reinhold Pub. Corpn., New York, 48 A.
- Raja, M.E. and Iyengar, B.R.V., 1986, Chemical pools of zinc in some soils as influenced by sources of applied zinc. Jour. Ind. Soc. Soil Sci., 34, pp. 34-97.

- Rao, B.R.M., 1977, Genesis and classification of soils of Rani-chauri district, Tehri-Garhwal (U.P.), thesis, Ph.D., G.B. Pant Univ., Argi. Technol, Pantnagar.
- Rao, Y.S., Mohan Raghu, N.G. and Rao, A.E.V., 1986, Micro-morphology of some soils in Cuddapah basin. Jour. Ind. Soc. Soil Sci., 34, pp. 225-229.
- Raychaudhary, S.P. and Mukerjee, K.C., 1942, Studies on Indian red soils, VI, Determination of mineralogical composition, Ind. Jour. Agric. Sci., 12, pp. 323-335.
- Raychaudhary, S.P., 1963, Saline alkali soils of India, Morphology, genesis of some selected saline and alkali soils of Bihar, U.P. and Punjab, Ind. Jour. Agric. Sci., 33, pp. 28-33,
- \_\_\_\_\_, 1966, Land and Soil. Nat. Book Trust India, New Delhi. 188 p.
- \_\_\_\_\_, 1974, In, soil map of India, All India Soil and Landuse Survey Organisation, 1970.
- Reh Commission, 1879, Report of Committee for investigating into the cause of deterioration of land by Reh in the Aligarh district, In, Alkali, Lands. Irrigation and drainage. Hilgard, E.W., 1886.
- Reiche, P., 1950, A survey of weathering process and product, In, Geol. Univ. New Mexico Press, Alhuquerque.
- Reineck and Singh, 1973, Depositional Sedimentary Environments, Springer-Verlag, New York, 50 p.

- Richards, L.A., 1947, Pressure-membrane apparatus construction and use, Agric. Engin, 28, pp. 451-460.
- \_\_\_\_\_, 1948, Porous plate apparatus for measuring moisture retention and transmission by soil. Soil Sci., 66, pp. 105-110.
- \_\_\_\_\_, 1954, Diagnosis and improvement of saline and alkali soils, U.S.D.A Handbook no. 60.
- Robert, L.J. and Beavers, A.M., 1966, Soil genesis, morphology and classification. Soil Sci. Soc. Amer. Proc. 30, pp. 621-624.
- Robinson, G.W., 1959, Soil - their origin, constitution and classification. Thomas Murby and Co., London.
- Rode, A.A., 1961, The soil formation process and soil evolution. V.S. Volynskaya and K.V. Krynochkina, eds. Israel, Prog. for Sci., Trans, Jerusalem, Available U.S., Dept. Commerce, Washington, In, Soil genesis and classification, Buol et al , 1973, Oxford and IBH Pub. Co., New Delhi.
- Roonwal, G.S., Khanna, S.S. and Prakash, A., 1967, Mineralogy of sand fraction in certain profiles of Hissar district (Haryana), Jour. Res., Punjab Agric. Univ., 4, pp. 168-173.
- Rose, A.W., Hawkes, H.E. and Webb, J.S., 1979, Geochemistry in mineral exploration, 2 ed., Academic Press, INC, New York, U.S.A. 657 p.
- Roy, K.K.G., 1954, Alkaline and saline soils, Bibliography soil science and fertilizer with reference to India. Bull. Indian Comm. Agric. Res., 74, pp. 66-72.

- Ruhe, R.V., 1956, Geomorphic surfaces and nature of soils, Soil Sci., 82, pp. 441-445.
- \_\_\_\_\_, 1967, New Mexico Bur., Mines Miner. Resour., Mem. 18, In, Adv. Agron, Daniels, et al., 1971, 23, 74 p.
- Russel, J.S. and Rhoades, H.F., 1956, Water table as a factor in the soil formation. Soil Sci., 82, pp. 319-328.
- Sahu, G.C., Nanda, S.S.K. and Panda, N., 1986, Identification, characteristics and transformation of clay minerals and coastal saline soils of Orissa. Jour. Indian Soc. Soil Sci., 34, pp. 585-592.
- Sailakshmiswara, Y., Rao, A.S. and Pillai, R.N., 1986, Quantity and Intensity Parameters of Potassium in Texturally Different Alluvial Soils, Jour. Ind. Soc. Soil Sci., 34, pp. 185-186.
- Samiei, A. and Chahal, D.S., 1986, Potassium Release in alluvial soils. Jour. Ind. Soc. Soil Sci., 34, pp. 757-761.
- Sartori, G., Ferrari, G.A. and Pagliai, 1985, Changes in soil porosity and surface shrinkage in a remolded saline clay, soil treated with compost. Jour. Soil Sci., 139, 6, pp. 523-629.
- Sehgal, J.L. and Stoops, G., 1972, Pedogenic calcite accumulation in arid and semi-arid region of the Indo-Gangetic alluvial plain of erstwhile Punjab (India), their morphology and origin, Geoderma, 8, pp. 59-72.

- Sehgal, J.L., Sharma, P.K., Randhawa, N.S., Singh, G. and associates, 1973, Salt affected soils of Sangrur district and their management. The Dep. Soils, PAU, Ludhiana, Res. Bull.
- Sehgal, J.L., 1974, Nature and geographic distribution of clay minerals in soils of different moisture regimes in Punjab, Haryana and Himachal Pradesh, Proc. Nat. Sci. Acad., India, 40 B, pp. 151-166.
- Sehgal, J.L., Dhir, R.P. and Murthy, R.S., 1986, Some taxonomic problems in major soil of the arid and semi-arid regions of India. Jour. Ind. Soc. Soil Sci., 34, pp. 111-124.
- Sen, A., 1958, Influence of climatic factors on salinity of Indian soils, Indian Jour. Agric. Sci., 28, pp. 61-64.
- Sharma, B.M., Yadav, J.S.P., 1986, Iron, manganese and phosphorus uptake and yield of rice in sodic soil amended with gypsum and Farmyard Manure, Jour. Ind. Soc. soil Sci., 34, pp. 849-854.
- \_\_\_\_\_, Nature and distribution of iron and manganese in sodic soils of Indo-Gangetic plains, Jour. Ind. Soc. Soil Sci., 34, pp. 64-68.
- Sharma, O.P., Gupta, R.K. and Dubey, D.D., 1986, Amelioration of a sodic clay soil with pyrites. Jour. Ind. Soc. Soil Sci., 34, pp. 155-159.
- Sharma, G.D., 1959, Nature and types of secondary minerals - aggregates, concretions, nodules and layers of soils. Jour. Ind. Soc. Soil Sci., 7, pp. 193-197.

- Singh, A.L., 1974, Utilization of saline and alkali soils in Aligarh district. *The Geographer*, XXI, 1, pp.63-75.
- \_\_\_\_\_, 1978, Economics and Geography of Agricultural Land Reclamation, pp. 31.
- Singh, A.L. and Ansari, M.A., 1984, Fertility status of Aligarh soils, *The Geographer*, XXXI, 1, pp: 32-33.
- Singh, B.P., 1980, Availability of potassium in some Haryana soils in relation to minerals, complementary ion crops, Dissertation Ph.D., HAU, Hissar.
- Singh, L. and Singh, S., 1972, Chemical and morphological composition of 'kankar' nodules in soils of the Vindhyan region of Mirzapur, India. *Geoderm.*, 7, pp. 269-276.
- Singh, O.P. and Datta, B., 1986, Form of potassium in some soils of Mizoram. *Jour. Ind. Soc., Soil Sci.*, 34, pp. 187-190.
- Singh, S.B. and Abrol, I.P., 1986, Effect of soil sodicity on growth, yield and chemical composition of Soybean. *Jour. Ind. Soc. Soil Sci.*, 34, pp. 568-571.
- Singh, R.N., Sahi, B.P. and Diwakar, D.P.S., 1986, Form of phosphorus in the Finer Mechanical Seprates of soils developed on different parent minerals and their genetic relationship. *Jour. Ind. Soc. Soil Sci.*, 34, pp. 476-483.
- Singh, S., Gavalapuri, V.N. and Khanna, S.S., 1974, Mineralogical distribution and soil formation of Hissar-II block, Haryana, *Proc. Ind. Nat. Sci. Acad.*, 40, pp. 326-337.

- Sindhu, P.S., Hall, G.F. and Sahgal, J.L., 1976, Influence of aeolian dust on the surface soil properties in the Central Punjab. *Annals of Aridzone*, 15, pp. 89-94.
- \_\_\_\_\_, 1976, Studies on some soils at varying stages of Pedogenic development in central Punjab I, Morphology and physico-chemical characterization. *Jour. Res. Punjab Agri. Univ.*, 13, pp. 23-34.
- Sindhu, P.S. and Gilkes, R.J., 1977, Mineralogy of soils developed in alluvium in Indo-Gangetic plain (India). *Soil Sci. Soc. Amer. Jour.*, 41, pp. 1194-1201.
- Smith, B.R. and Buol, S.W., 1968, Genesis and relative weathering intensity studies in three semi-arid soils. *Soil Sci. Soc. Amer. Proc.* 32, pp. 261-265.
- Smith, G.D., 1968, Soil classification in the United States. In, *World Soil Resources Rep.*, 32, pp. 6-24. FAO, Italy.
- Smith, G.D., Allaway, W.H. and Riechen, F.F., 1950, Prairie soils of the upper Mississippi valley, *Adv. Agron.* 2, pp. 157-205.
- Sopher, C.D. and Baird, J.V., 1978, *Soils and soil management*, Reston Pub. Co. Inc., Reston, Virginia, 238 p.
- Sudhansu, K., Ghosh, and Kapoor, B.S., 1982, Clay minerals in Indian soils. *Jour. Indian Soc. Soil Sci.*, pp. 705-706.
- Talashilkar, S.C. and Vimal, O.P., 1986, Studies on increasing the use efficiency of N and P fertilizers in Combination with city solid waste. *Jour. In . Soc. Soil Sci.*, 34, pp. 780-784.

- Tamhane, R.V. and Namjoshi, N.G., 1959, A comparative study of black soils formed from different parent rocks. Jour. Ind. Soc. Soil Sci., 7, pp. 49-63.
- Tamhane, R.V. and Karale, R.L., 1967, Studies on the basaltic soils of Bombay Deccan. Jour. Ind. Soc. Soil Sci., 15, pp. 269-279.
- Torrent, J., 1976, Soil development in a sequence of river terraces in northern Spain, Catena, 3, pp. 137-151.
- U.S.D.A., 1954, Diagnosis and improvement of saline and alkali soils, USDA Agri. Handbook, 60.
- U.S.D.A., 1968, Diagnosis and improvement of saline and alkali soils, USDA Agri. Handbook 60, 160 p.
- Vepraskas, M.J., Baker, F.J. and Bouma, J., 1974, Soil mottling and drainage in a Mollic Hapludalf as related to suitability for a septic tank construction, Soil Sci. Soc. Amer. Proc., 38, pp. 497-501.
- Verma, S.L., 1973, Survey of the quality of the some typical underground waters in Haryana and their effect on soil properties. Thesis M.Sc. Haryana Agri. Univ., Hissar.
- Vorm Vander, P.D.J., Diest, Van A., 1979, Aspect of the Fe and M.N. Nutrition of rice plants. II iron and manganese uptake by rice plants growth on aerobic water Cultures. Plant Soil, 52, pp. 19-29.
- Wadia, D.N., 1981, Geology of India, New Delhi, p. 365.



- Wadia, D.N. and Auden, J.B., 1939, Geology and structure of Northern India. Mem. G.S.I., 73, Delhi, pp. 134.
- Wadia, D.N., Krishnan, M.S., and Mukherjee, P.N., 1935, Geological Foundations of the soils of India. Rec. G.S.I., 63, pp. 361-391.
- Warshaw, C.M. and Roy, Rustum, 1961, Classification and a scheme for the identification of layer silicates, G.S. Americ. Bull., 72, pp. 1455-1492.
- Went, B., 1907, The salts of Sambhar lake in Rajputana, and of the saline efflorescence called 'Reh' from Aligarh in the U.P. Provinces. Rec. G.S.I., XXIV, I, pp. 68-69.
- W.H.O., 1934, Guidelines for drinking water quality, 1, Recommendations, Geneva.
- Yadav, J.S.P., 1986, Degradation and crop production problems of soil and water resources in India. Jour. Ind. Soc. Soil Sci., 34, pp. 660-674.
- Yuan, H.F., Chang, Y.S., 1978, Effect of available silicon in paddy soil on the growth of rice plants. Bot. Bull. Acad. Sinica, 19, pp. 125-198.